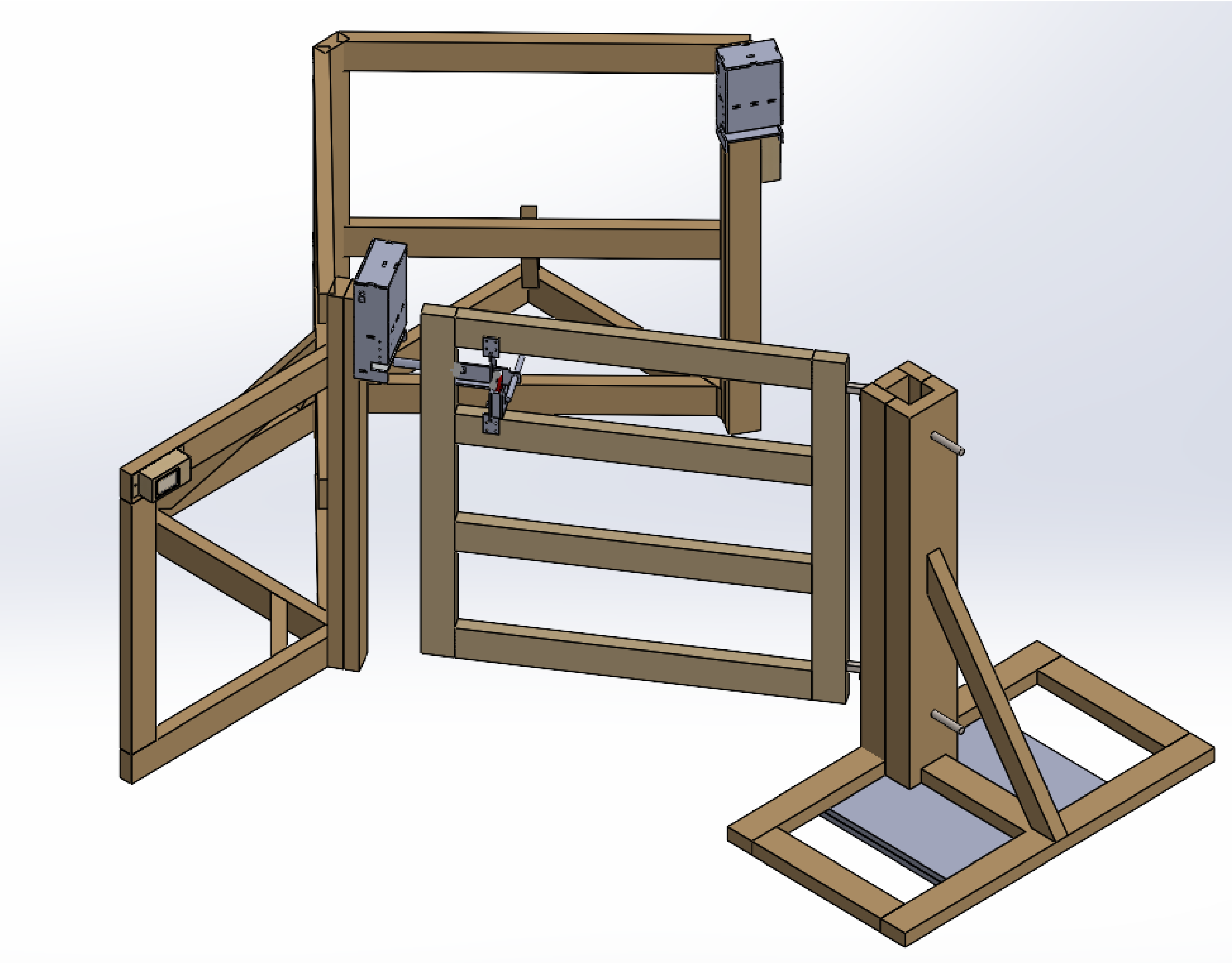

Design Report
FEEG6013 Group Design Project

28

Access Gate for Disabled Ramblers

Design of a gate/opening/barrier that allows mobility scooters through but excludes motorcycles.

Project Summary:
Access to outdoor spaces is crucial to the health and wellbeing of every individual. Unfortunately, some structures on public rights of way (PRoWs) impede the freedom of mobility scooter users, preventing them from accessing areas they are lawfully entitled to be, and excluding them from essential recreational activities.

Of all the structures on PRoWs, motorcycle-deterring solutions prove to be the most problematic for mobility scooter users, due to the similar features shared by both vehicle types. Many landowners, concerned about motorcycles damaging paths, are reluctant to install accessible structures that can accommodate mobility scooters. To address this issue, Disabled Ramblers provided us with the challenge of designing a gate which permits mobility scooter access, but prevents motorcycle access.

Initial explorations of mechanical solutions proved to be unsuccessful; complex contraptions developed were determined to be impractical and difficult to implement. Following further research and consultation with stakeholder groups, we discovered illegal motorcycle access on PRoWs is mostly confined to urban fringes. Due to the prevalent grid infrastructure in these areas, the feasibility and subsequent implementation of electronic solutions was explored. This culminated in the development of an RFID-input electronic latch, which was subsequently integrated into a kissing gate structure to preserve pedestrian access, whilst limiting the access of motorcycles.

The design process involved initial modelling, prototyping, and subsequent testing to improve alignment, functionality, and user experience.

This prototype promises a significant improvement to mobility scooter user experience when compared to current kissing gates in use – by facilitating a low-effort, one-handed operation, it allows users to pass through comfortably.

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6) Participants & Volunteers
7) The Disabled Ramblers Charity
8) The Disabled Ramblers' Community
9) The Centre for Outdoor Accessibility Training

Abbreviations

AC – Alternating current
CAD – Computer Aided Design
COAT – Centre of Outdoor Accessibility Training
DC – Direct current
EDMC – Engineering Design and Manufacture Centre
LAF – Local access forums
PDS – Product Design Specification
PRoW – Public right of way
PV – Photovoltaic

Terminology

Table 0 Terminology's used throughout the report [1].

Bridleway	Any route where horses are allowed
Enclosure	Area within which the gate of a kissing gate swings or the area between a part of gates comprising one structure
Gap	Unimpeded way through a boundary together with any side structure
Gate Leaf	The main body/frame/Panel of a gate that opens and closes as a single unit.
Gate Stile	A vertical upright section of a gate, normally the outermost uprights.
Hang Post	The post to which a gate is hung, where the hinges are situated
Hang Stile	The upright section of the gate where the hinges are fixed and where it connects to the post. (End of the gate that pivots).
H-Frame	A Metal frame, in a "H" style arrangement with a section/cross member buried in the ground
Hinge Hook	A simple pin on a piece of plate that provides the male portion of a hinge on a post for an eyebolt on a gate assembly to mount to.
Hook to Bolt	A hinge hook with a threaded section of rod attached, to allow it to be mounted through a hole in a post and fixed in place with a nut.
Hook to Plate	A hinge hook with a plate with multiple holes for bolts to pass through
Kissing Gate	Device consisting of a hinged gate that is constrained to swing between two posts at the opening of an enclosure forming part of the structure, and which allows the passage of legitimate users, whilst preventing the passage of animals, etc.
Offset Hinge set	Otherwise known as the self-closing hinge set. This only uses the force of gravity to self-close, with no hydraulics involved.
Pedestrian Gate	Device hinged at one side installed in a boundary such as a fence, hedge or wall which acts as a barrier to animals and motor vehicles, but allows the passage of pedestrians and their dogs, and mobility vehicles.
Pedestrian/Access Stile	Fixed device allowing the passage of pedestrians over or through a fence, wall or hedge, while forming a barrier to farmed animals and many dogs, as well as cycles and mobility vehicles.
RADAR lock	Lock operated by a key (RADAR Key), normally only available to disabled people
Self-closing gate	Gate which returns without intervention to a position touching, or in line with, the closing post
Shoot Bolt/Spring Bolt	A moveable bolt, normally attached to the gate, to which the latch restrains or which extends into a profile, to prevent the gate being opened. Following the release of BS 5709:2018, these are usually found in a "D-loop" arrangement to reduce risk of catching or harm as users pass through the gate.
Slam Post	The post to which a gate closes to, often where the latching interface occurs.
Slam Stile	The upright section of the gate where the latch is fixed and which latches closed. (End of the gate that swings)
Trombone Handle	A handle that curves over the top of the gate, allowing easy operation
Pawl Housing	A box that encases the latching mechanism
RFID housing	A box that encases the RFID reader

1. Context & Brief

Ensuring equal access to outdoor spaces for all individuals, regardless of their mobility challenges, is a fundamental aspect of creating inclusive communities. In recent years, the number of people in the United Kingdom with some form of disability has risen to approximately 25% of the total population – a figure which is expected to rise further [2]. Within that group, approximately half of people struggle with mobility issues, and rely on wheelchairs or mobility scooters to navigate their surroundings - with many seeking opportunities to connect with nature and enjoy the benefits of outdoor recreation. However, the presence of man-made barriers such as stiles, steps, and kissing gates pose significant obstacles to those using wheeled mobility aids, hindering their ability to fully participate in countryside activities [3].

Disabled Ramblers, a national charity dedicated to facilitating access to the countryside for disabled individuals, has attempted to enhance accessibility in outdoor environments by campaigning for the replacement of inaccessible barriers with more inclusive alternatives. Despite the clear benefits of accessible gates, landowners often express concerns about potential misuse by unauthorised vehicles, particularly motorcycles - highlighting the complexity of the challenge at hand.

To address these issues, this project sought to develop innovative gate designs that accommodate the needs of wheelchair and mobility scooter users, whilst effectively preventing unauthorised vehicle access. By considering factors such as weight, shape, and size, the project aimed to create low-cost, easily manufacturable solutions that are acceptable to both mobility scooter users and landowners.

1.1. Project Aim

From the assigned design brief, the project aim was derived:

Design and manufacture a prototype structure that is both motorcycle-deterring and more accessible for mobility scooter users than current designs on the market.

1.2. Project Objectives

To help achieve the project aim, distinct objectives were set:

1. Investigate existing designs and viewpoints of relevant stakeholders.
2. Form a product design specification and identify areas for improvement.
3. Produce multiple design solutions that resolve the design brief.
4. Construct and test full-scale prototype of a selected design.
5. Use feedback from testing to suggest improvements to design.

2. Initial Research

Due to the limited amount of prior knowledge we had regarding the project, primary research was conducted to provide the group with sufficient information to inform our design process. The first goal of the research was to identify potential stakeholders in the project, such that their input could be recorded. In addition, we also investigated existing gate designs - using first-hand experience to analyse their best and worst features, such that they could potentially inspire improved designs.

2.1. Stakeholders

Through discussions with our charity liaison, Shail Patel, we were able to identify potential stakeholders, both internal and external to the University, such that their opinions could be collated, and later used to inform our design choices. Fig. 1 identifies and categorises all the potential project stakeholders.

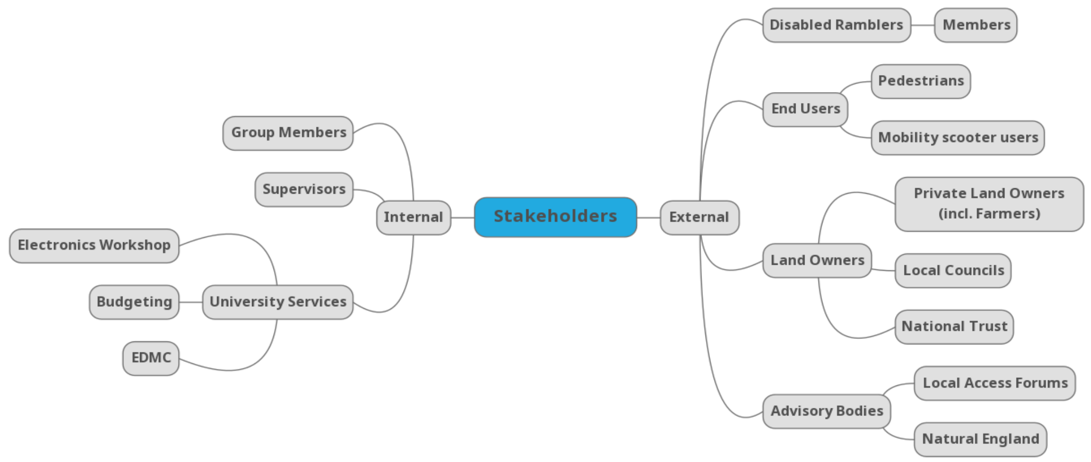


Fig. 1. Stakeholders mind map.

After identifying the involved parties, further research was conducted to understand their potential interests and concerns with regards to our project. This information is presented in Table 1.

Table 1
Background information regarding identified stakeholders.

Stakeholder	Background Information
Disabled Ramblers	• Registered charity. • Provided the project brief. • Campaign for a more accessible countryside. • Provide rambling advice to mobility scooter users.
Landowners/Highway Authorities	• Responsible for the installation and maintenance of structures on public rights of way (PRoWs).
Advisory Bodies	• Responsible for providing advice to highway authorities regarding installations and maintenance of right of ways. • Natural England operates at a governmental level, whereas Local Access Forums advise local councils on individual cases.
End Users	• Any persons legally accessing a pedestrian footpath. • Includes mobility scooters and pedestrians.

2.2. Existing Gates & Structures

Public rights of way (PRoWs) around the country utilise at least one of four methods to allow passage over land boundaries: gaps, barriers, gates and stiles. Each solution has its own benefits and drawbacks; gaps provide the best accessibility to the right of way; however, they provide no restrictions to motorcycles or livestock. On the other hand, stiles prevent livestock and motorcycles, but limit access to able bodied individuals only. Gates and barriers, like those shown in Fig. 2, are currently seen as the best compromises; however, they are not without flaws.

Fig. 2. Examples of A-Frames (left), Kissing Gate (middle), Standard Two-post gate (right).

2.2.1. Bike Inhibitors

Bike inhibitors represent a simple barrier solution based on the principal of dimensional restriction, typically featuring two upright posts angled towards each other in an 'A' shaped configuration. These posts serve the purpose of creating a narrowing - posing a challenge for motorcycles, with their commonly wider handlebars. Unfortunately, due to the similar profiles of the two vehicle types, some mobility scooters are unable to pass through A-frames.

2.2.2. Kissing Gate

The kissing gate is a design built on the principal that vehicles such as motorcycles have a footprint incompatible with a narrow, enclosed area. As the gate leaf is swung within the enclosure, a widening is created between the gate leaf and the opposing structure, allowing pedestrians to pass through.

To permit access for mobility scooters, the shoot-bolt on the gate leaf can be retracted by unlocking a RADAR padlock (discussed further in section 5.2.2.1). This allows the gate leaf to be swung outside of the enclosed area, creating a wider opening - sufficient for a mobility scooter. Users of this feature commonly find it challenging to operate; the 180-degree hinges used in the design, paired with the offset enclosure area means the gate leaf may only leave the enclosed area in one direction. This produces a scenario where the driver is required to simultaneously hold the gate leaf and reverse their mobility scooter, such that the gate leaf can be pulled towards them.

Furthermore, effectiveness of this solution as a motorcycle-deterrent is hindered by two main issues: the availiability of the RADAR key, and the lock's positioning on the gate. Despite the intention of the RADAR key to be restricted to a select group of individuals, the lack of regulation in this area led to the mass duplication and the readily availability of it in the market. Subsequently, the positioning of the lock on the gate forces users to adopt unconventional body movements to operate them.

2.2.3. Two-Post Gate

The Standard Two-post gate is another popular option that can be found throughout the countryside. Models like the 'Aston 2-way' are favoured within the user group due to its self-closing, bi-directional functionality and convenient 'trombone handle' latch. The feature provides users with more leverage, resulting in an easier operation when unlatching.

Despite its popularity, this gate design is far from ideal, posing similar challenges to kissing gates, where users are required to adopt unconventional body positions to operate it efficiently. The handle is positioned close to the fence line - out of reach - forcing users to either position their scooters parallel with the fence line, or reach over the front of their scooter.

2.2.4. Broughton Moor Accessible Gate

A unique, standalone accessible gate design can be found at Broughton Moor Forest (Cumbria). This gate uses a seesaw inspired mechanism, which allows the gate to be unlatched at a significant distance away from the fence-line. As the user approaches the gate, they reach a horizontal handlebar (Fig. 3) with an arrow instructing them to pull the bar towards them.

Fig. 3. Broughton Moor Gate.

The bar extends to the fence line, where it is connected to an L-shaped steel plate (here referred to as an L-piece) via a hinge. This L-piece is also attached to the latch housing via another hinge. This is depicted in Fig. 4.

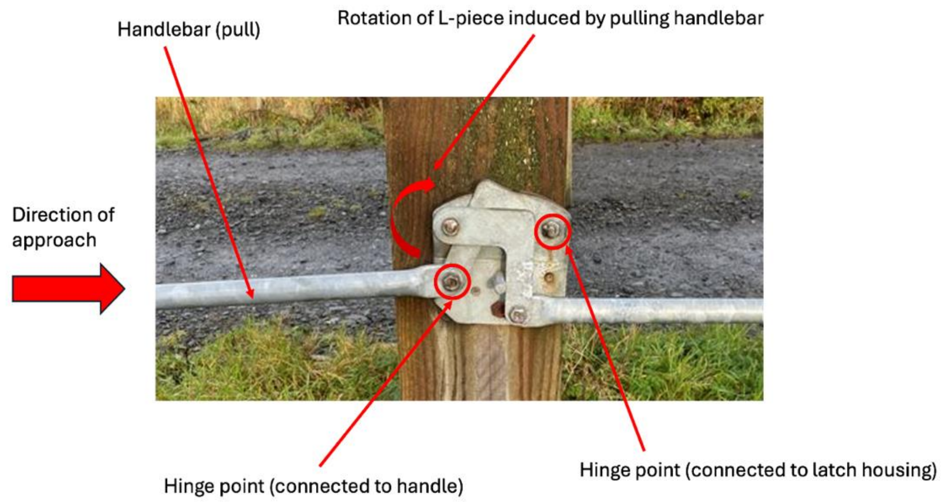


Fig. 4. Latching mechanism on Broughton Moor Gate.

Pulling the handlebar causes the L-piece to rotate away from the user. Due to the shape of the L-piece and the position of its hinges, as it rotates, it travels higher up the gate post. When the spring bolt is latched, the vertical displacement of the L-piece pushes the spring bolt up and out of the catch, forcing the gate open; allowing the user to pass through (Fig. 5).

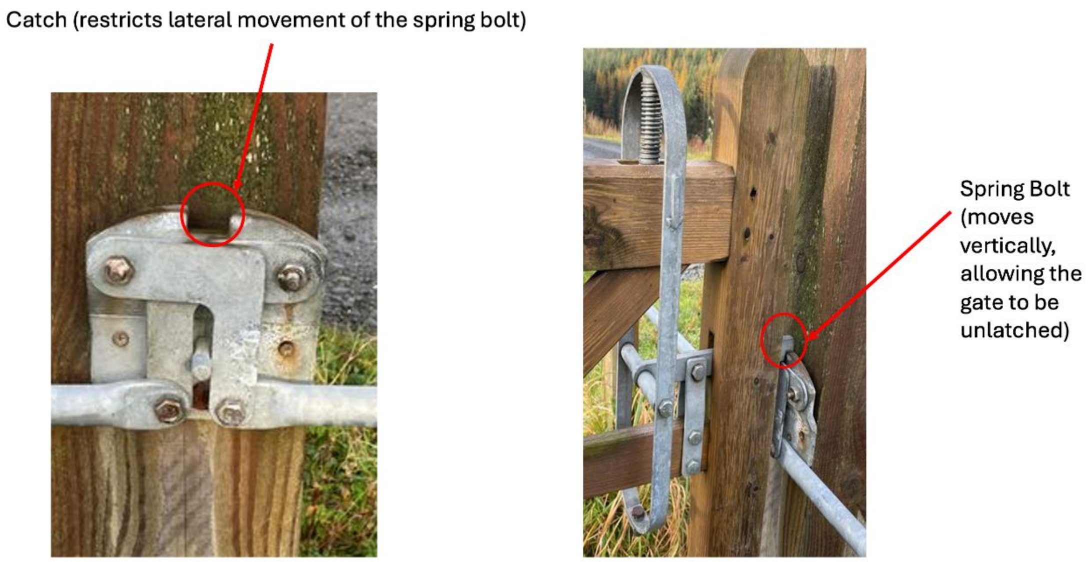


Fig. 5. Latch on Broughton Moor gate.

This gate design aims to address the issue of poor positioning of latching mechanisms, whereby most gates require the user to unlatch the gate at the fence line. Therefore, this design achieves greater ease-of-use, whilst providing the user with a more comfortable experience.

2.2.5. University of Arkansas Bump Gate

Electronic gates are not common and have several fundamental flaws when compared to common agricultural gates – most obvious being the requirement for power and regular maintenance. Despite their limitations, electronic latching mechanisms are used for their convenience, reducing the effort required from the user. One such design was developed by students at the University of Arkansas. Their 'Bump Gate' design is a remote-controlled assisted gate which aims to improve the quality of life of agricultural workers, who are ageing or have disabilities, by eliminating the need for them to get in and out of their vehicles.

It is a low-cost system involving a solenoid powered gate latch and limit switches to control a lifting plate as shown in Fig. 6. The solenoid, activated by a remote control, raises the latch tongues, allowing the gate to be pushed open. The latch stays open for approximately eight seconds. Upon contact with the lifting plate, a microswitch triggers a light to signal that it is safe to proceed. Due to the angled shape of the pawl pieces, the gate can self-close, eliminating the requirement for complex timing mechanisms.

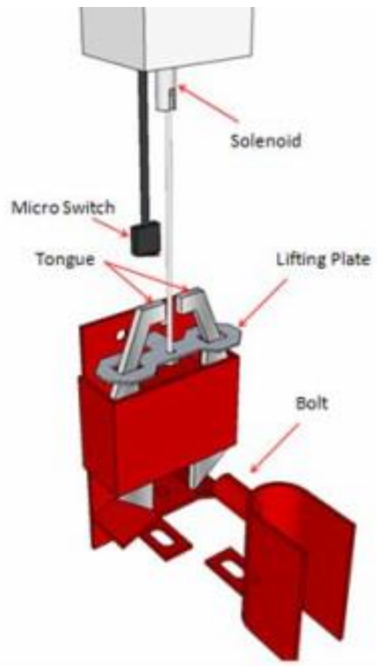


Fig. 7. Image of AgrAbility Project Latch Design [4].

2.3. COAT Visit

The Centre for Outdoor Accessibility Training (COAT) based at Aston Rowant National Nature Reserve is a specialist access centre funded by Natural England. The centre provides policy makers and those affiliated with highway authorities with the opportunity to interact with different structures commonly used on PRoWs – allowing them to make more informed decisions.

To help us get more familiar with structures on PRoWs, we completed a group visit to the centre. Whilst at the centre, we met with Val Woods, the site manager, and Tom Bindoff – founder of the gate manufacturer Centrewire, and a consultant in the development of the British Standard relating to the installation of structures on PRoWs (BS5709:2018). Initial discussions with Val and Tom gave us an insight into which structures are preferred by mobility scooter users, and common issues they face on PRoWs.

The centre contains a circuit of structures suitable for installation on pedestrian footpaths. During our visit, we were loaned a Tramper mobility scooter, and attempted to complete the route without leaving the seat. This gave us the opportunity to understand the function of each structure, whilst also getting an appreciation for the difficulties one faces when interacting with them on a mobility scooter.

2.3.1. Learnings from the Visit

One of the most prevalent issues that we encountered during our visit was the awkward placement of unlatching mechanisms - the handles and locks used on 'scooter friendly' structures are not well positioned for those in mobility scooters to reach. We were not able to use the regular handles without getting up from the mobility scooter seat, and so we were recommended by Val to use a walking stick to open the latch mechanisms, see Fig. 7. While we were able to open the latches this way, it was very inconvenient, and we acknowledged it would likely be significantly more challenging for those with poor upper arm control or strength. Compounding this issue, once the gate had been unlatched successfully, we also found it very difficult to pass through the gate before it latched closed again.

Fig. 6. Various methods of unlatching the gates.

Whilst trying to pass through the motorcycle-deterring structures (the kissing gate and bike inhibitor), we discovered that there was limited room to manoeuvre. Additionally, the kissing gate presented a variety of challenges - the biggest being the position of the RADAR lock. Requiring complex manoeuvring or stretching from the seat of the scooter, the lock and shoot-bolt are poorly designed. Even if the padlock and shoot-bolt is withdrawn, the issues do not cease. The next difficulty with operation lies with the opening of the gate leaf. One direction of operation was without issues, as you could push the gate leaf forwards. However, in the opposite direction, the gate leaf had to be pulled back towards the user, whilst simultaneously controlling the mobility scooter.

Ultimately, this visit helped us to identify aspects of existing designs that could be improved upon, providing us with a basis to build our designs from.

2.4. Static Profiles

Fig. 8. Example of image used for pixel measurement [5].

It was quickly obvious we needed to have access to datasets of sizes for mobility scooters, powered wheelchairs, and motorcycles to aid the in the analysis of existing solutions and generation of new concepts.

The first step in data gathering for mobility scooters involved reaching out to manufacturers and authorised dealers for information. However, this approach proved fruitless, with minimal to zero response from the respective manufacturers. We subsequently replaced this method with a new approach: retrieving dimensions from online databases. Sales websites such as 'Mobility Giant' were visited, and the stated dimensions that we deemed useful were recorded. This was done for 4-wheel, 3-wheel mobility scooters and powered wheelchairs. For dimensions that were not listed online, pixel measurement was used on suitable images. To reduce parallax error, the images used were the ones most perpendicular and centred with the camera, an example of which is shown in Fig. 8 [5].

As for the study of motorcycles, a filter of models with 150cc and above was set for this research. This was due to the significant difference in the size of motorcycles having less than 150cc. Unlike mobility scooters, data for motorcycles was more readily available from manufacturers. The dimensions of interest for around forty different motorcycles were compiled.

Having gathered the dataset (Appendix A), it was then used to create a static envelope (Fig. 9) of 3-wheel and 4-wheel mobility scooters, powered wheelchairs, and motorcycles for use with some of our possible gate concepts. We also used anthropometric data to estimate measurements for body parts such as shoulder width and shoulder height [6] and included these in the profiles.

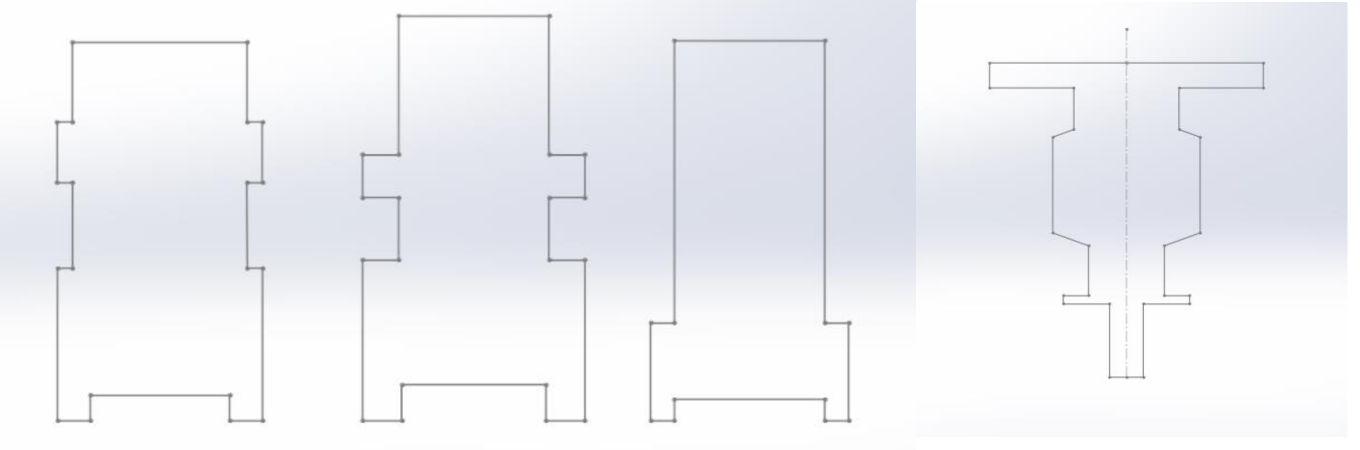


Fig. 9. Static profiles. 4-wheel (left), 3-wheel (centre left), powered wheelchairs (centre right), motorcycle (right).

After assembling all these static profiles, it was determined that there was too much overlap between the profiles of mobility scooters and motorcycles, since extra clearance must be provided for mobility scooters, as they are less manoeuvrable than motorcycles. Furthermore, motorcycles can drastically reduce their width by turning their handlebars, making the implementation of a width restriction more complicated.

2.5. British Standard

The British Standard Institution (BSI) is an organisation that publishes standards relating to various products and services. With regards to designing structures for installation on PRoWs, BS5709:2018 was created to provide guidance on best practice. Although not enforced by law, the recommendations made within BS5709:2018 are often echoed by advisory bodies such as LAFs and Natural England.

The scope of the most recent publication provides guidance on different aspects of the design of gaps, gates and stiles. Aspects covered within the standard include:

- Sizes of structures
- Minimum clearances
- Maximum opening forces required for gates
- Minimum closing times of gates (from fully open position)
- Sharp edges
- Distance of structure from roads
- Maintenance requirements

Although this standard is highly regarded by members of the Disabled Ramblers charity, as a design team we decided not to let the standard inhibit our design process; neglecting the standard in cases where we felt that it was detrimental to the functionality of our design.

2.6. Material Considerations

An important consideration of any design we developed was the longevity of the required materials; a factor that is strongly related to cost and sustainability.

We were anecdotally informed at the COAT that timber is a popular gate material due to its natural and aesthetically pleasing look, which easily blends into outdoor environments. Despite this, timber gates generally require higher levels of maintenance and are not as durable as metal alternatives. Furthermore, they are also susceptible to warping with weather variations - to reduce this, the wood is treated. Timber is generally UC4 treated according to BS 8417, which is valid for wood that is used outdoors and in permanent contact with the ground. This gives the timber an expected service life of at least 15 years for ground contact applications [7]. Despite treatment, warping is not completely eradicated, thus timber gates are susceptible to alignment issues, as the structure of the gate changes over time.

The alternative material commonly used in agricultural gates is galvanised steel. This provides a strong and sturdy structure that can withstand exposure to extreme weather and loading conditions. Centrewire galvanise their steel to BS EN ISO 1461 [8]. Through galvanising, the steel is expected to last around 30 years in the harshest soils without deteriorating or warping [9].

2.7. Local Access Forums

Local Access Forums (LAFs) are advisory panels that converse with local councils and other authorities about plans or policies that may impact public access to outdoor recreation. There are many LAFs around England, each independent, representing the interests of different demographics [10].

LAFs contain representatives of landowners, disabled persons, and conservationists (among others), such that they can provide recommendations based the opinions of informed individuals with diverse backgrounds. Since LAFs advise on issues regarding accessibility, it was thought that they would be able to provide some insight into which solutions are preferred when a structure is installed on a PRoW.

Emails were sent to a variety of LAFs around England, containing questions regarding motorcycle access and accessible structures on PRoWs. The question set can be seen below:

1. *What do you consider to be the most accessible gate design(s) for mobility scooter users?*
2. *What do you consider to be the least accessible gate design(s) for mobility scooter users?*
3. *How big is the issue of motorcycles illegally using rights of way? Are motorcycles on rights of way a common and frequent issue for landowners?*
4. *What are the consequences of motorcycles using rights of way (from the perspective of landowners)?*
5. *What gate designs/structures do you consider to be effective at prohibiting motorcycle access?*

Responses were received by several LAFs, each providing their own unique insight into the questions raised. The responses are summarised below:

- Accessible structures tend to be recommended in accordance with BS5709:2018 – a gap is always the preferred option; stiles are the least preferred.
- Motorcycles are more of an issue near centres of population ‘such as the Ridgeway Trail and the Peak District’.
- Despite being a bigger issue in the Peak District, the problem is limited to a few routes.
- Problems arising from motorcycles using PRoWs include: damage to the ground, damage to gates, and terrorizing livestock.
- Motorcycles on PRoWs discourage landowners from installing accessible structures.

2.8. Questionnaire

An important aspect of our design process was to consider the user experience; recognising the significance of the perspectives of the Disabled Ramblers’ community, which have often been overlooked in current gate design and implementation.

Despite efforts to find quantitative data, our search primarily yielded informal sources such as Facebook posts and anecdotal comments. To obtain more definitive opinions from a wider group of people, we decided to produce an anonymous online questionnaire. We compiled a set of questions based on recurring themes from: our research, insights from the COAT visit, and prevalent opinions expressed within the community. Our main aim was to gather both quantitative and qualitative insights into individuals' perceptions of bike inhibitors and kissing gates — structures frequently criticised within the community. By investigating these sentiments, and delving into the justifications behind them, we aimed to identify trends and potential areas for improvement.

To maximise respondent engagement and diversity, we distributed our questionnaire on the Disabled Ramblers’ Facebook page, recognising it as a platform with extensive reach within our target demographic. See Appendix B for a full list of questionnaire questions and responses (related ethics application, ERGO 89811).

2.8.1. Summary of Responses

We received 56 responses to the questionnaire.

Some of the findings were anticipated:

- The Tramper was the most owned mobility scooter brand.
- There was a lack of self-reported evidence of motorcycles on paths while rambling, with 88% stating that they either occasionally, rarely, or never see evidence for the presence of motorcycles.
- Pushing away was considered to be the easiest motion to perform on a mobility scooter.
- 71% of respondents reported restrictions in lower limb movement, 54% indicated limited upper limb strength, and 31% mentioned restrictions in upper limb movement.

These findings were important in determining the functions we needed to incorporate into our design concepts. For example, any mechanism that was designed to involve user input did not require movement out of a mobility scooter. Moreover, all designs required limited, low-intensity upper arm interaction, ideally pushing away.

However, other findings were more significant and surprising:

- When asked about RADAR locks on kissing gates, only one third of respondents rated their experience as negative.

This finding was contradictory to prior research and feedback; we were under the impression that RADAR keys were largely disliked. The respondents were given the opportunity to provide justification, of which 27 obliged. The responses were varied, with many citing inconvenience, poor quality, and the necessity of using a lock (Fig. 10). Valid concerns were also raised, including: the obstruction of access for those without keys, a lack of awareness surrounding installation, and difficulties faced by individuals with poor muscular control.

- Bike inhibitors proved universally unpopular, with no positive responses received.

Accompanying feedback informed us that this was largely because users physically cannot fit their mobility scooters through them, among other reasons (Fig. 10).

- 85% of encountered gates were identified to be in fair to poor condition.

This result underscored the importance of ensuring our design remained uncomplicated and easy to maintain.

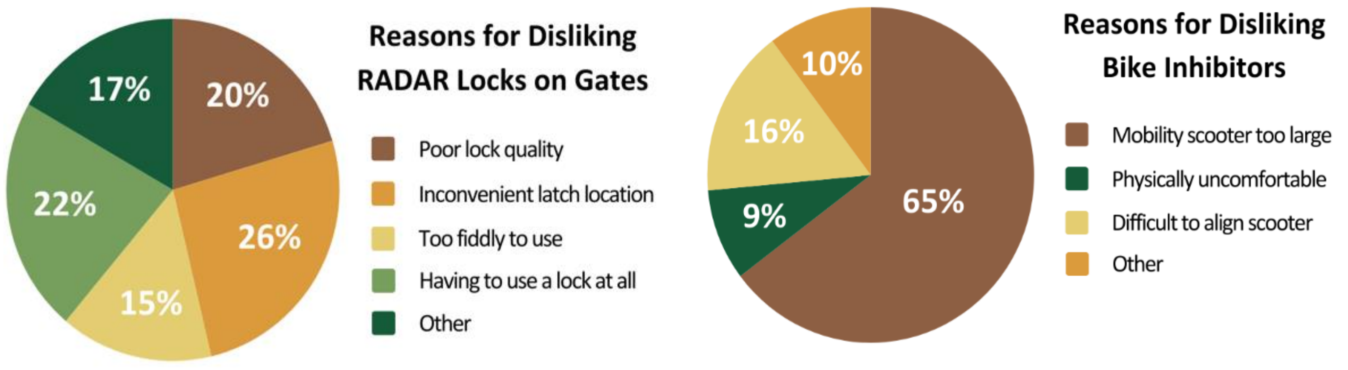


Fig. 10 Pie-charts breaking down RADAR lock and bike inhibitor feedback from the questionnaire.

In addition to multiple choice questions, participants were able to provide written feedback. The majority of written comments received were centred around kissing gates not being large enough, or locks and latches being poorly positioned. Moreover, there appeared to be a general sentiment that current gates are not designed or installed with disabled persons in mind, and that there is an assumption that wheeled mobility users are accompanied by able-bodied people.

It's important to note that these opinions represent a small fraction of mobility scooter users, and may not fully represent the broader population. While it's possible that these views reflect a vocal minority passionate about outdoor accessibility, we believe they are significant enough to inform our gate design assumptions.

2.9. Summary of Findings

Based on the various perspectives we had gathered, and the research conducted, there were several key points that warranted further consideration as the project progressed:

- The lack of mobility scooter standardisation complicates designing structures based solely on accommodating size differences between scooters and bikes.
- Adherence to BS5709:2018 is advised but not obligatory.
- Steel structures provide enhanced structural integrity and reduced maintenance costs when compared to timber.
- Multitasking presents challenges whilst opening gates.
- Current locks and handles are sub-optimally placed for those in mobility scooters.
- Bi-directional, self-closing gates are essential.
- User independence is strongly desired.
- Mobility scooter users should remain in their seats as they pass through the structure.
- At least one hand should remain free when passing through the gate, such that the mobility scooter can be operated.
- Varying levels of disability across users makes it difficult to produce a design that is all-encompassing.

- Achieving complete satisfaction across all stakeholders will be unattainable.
- Maintenance (or lack thereof) is a common issue for gates on PRoWs.

3. PDS

Prior to commencing our design generation, we created a Product Design Specification (PDS), that we could strive for and critique against. The full PDS is listed in Appendix C, but one of the most significant informing pieces of material was the 3Rs document shown in Table 2. This is a list of requests, requirements and restrictions that were generated with the input from our stakeholders.

Table 2
The Requirements, Restraints and Requests document.

Requirements	• Materials must non-toxic and conform with British Law for public structures. • Some Mobility scooters require a 3m diameter area to manoeuvre. • Must accommodate 173cm as the guide minimum length of a mobility scooter. • Must allow for two directions of travel. • Must conform to Equality Act 2010.
Restraints	• Mobility scooters will not provide a source of power to the gate (Battery syphoning not possible). • For historical sites, the ground may not be disturbed or damaged. • The ground through before and after must remain level and flat. • Should be suitable for mobility scooters with 4” ground clearance. • Should be stockproof. • Should function as a self-closing gate.
Requests	• Gate permits access for pushchairs and horse riders. • Gate would contain no electronics. • Gate is easily maintained. • Gate doesn’t use a RADAR lock. • Gate compliments the surrounding environment. • Gate positions input mechanism into reachable area. • Gate is made from sustainable materials. • One-hand operable. • BS 5709: 2018 compliant.

This and the PDS were living documents; referred to throughout the design process to prompt ideation by helping to break the whole task into smaller aspects that could be prioritised and tackled separately. Moreover, the PDS was used alongside methods such as ranking matrices, checklists, votes, and direct feedback from Disabled Ramblers to evaluate individual designs. It was also used to compare our ideas against the competition best, such that we could analyse where our proposals were better or worse.

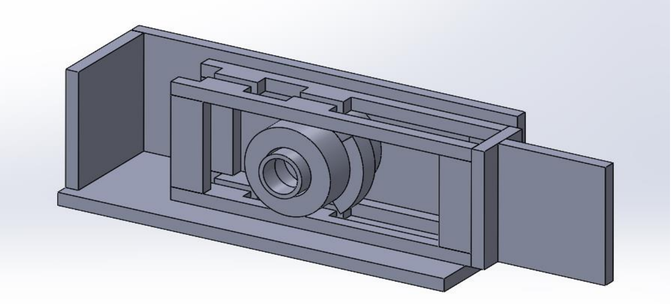
4. Design Process

All the designs considered were inspired by an input-based approach; a list of all discriminating factors/mechanisms between mobility scooters and motorcycles was created to identify potential avenues for a design. The inputs listed included: weight, 2D/3D Profiles, weight distribution, number of axles with two wheels, electrical input from the mobility scooter, the thrust from the mobility scooter, and physical input from the driver. Once potential designs had been developed, they were compared against the PDS to highlight areas for improvement, allowing them to be further refined.

4.1. Initial Ideas

After identifying a repeated issue with the use of RADAR locks, alternative locking systems were explored, ranging from electronic to manual. With users struggling to reach the location of the padlock, a new key design was developed that could be controlled from distance. Requiring mobility scooter users to carry around a new far longer key would be an inconvenience, so avenues were explored to incorporate the key into a walking stick, an item already frequently used by ramblers to assist in opening gates. The walking stick would have a removable end that would reveal a custom key mechanism they could place and turn in the lock. A possible design would feature spring-loaded wedges as an alternative to a standard key and barrel configuration. This mechanism would allow the wedges to compress inwards as the key is inserted through the lock’s outer collar, and then expand out into the custom grooves of the lock. The wedges would then bite in the lock as it is turned and draw back a sliding bolt.

The conversion of rotational to linear motion is a common mechanism found in the latches of most doors, using an example latch and some laser cutting, it was possible to reproduce the mechanism on a larger scale. Shown in Fig. 11 below is a CAD model and prototype, demonstrating a change in latch position depending on rotation of the barrel. Modelling from wood with larger tolerances reflected high amounts of friction, leading to seizing in the mechanism. Therefore in a full scale prototype, aluminium should be used to provide functionality.



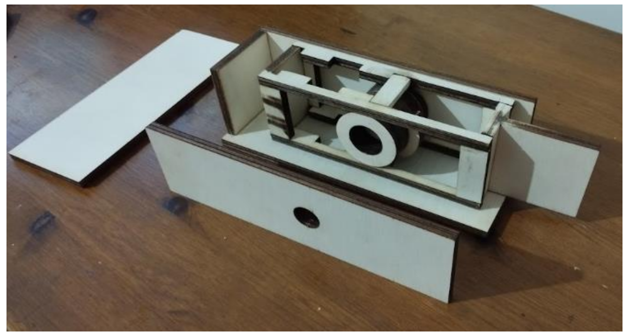


Fig. 11. SolidWorks of lock (left) laser-cut prototype lock (right).

The lock would be mounted onto the slam-stile and interact with self-closing pawls. These pawls would have to be encased to prevent tampering otherwise the gate could be opened without the need for a key. This configuration is displayed in Fig. 12 below.

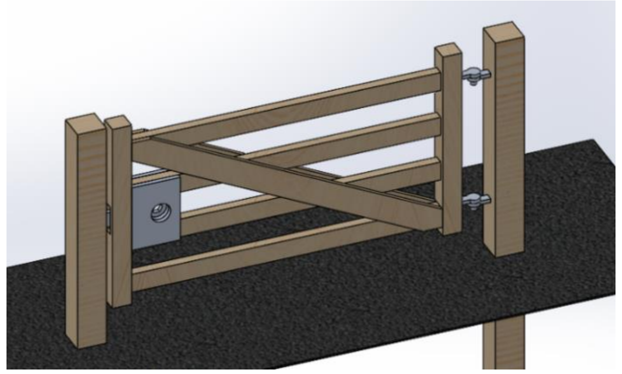
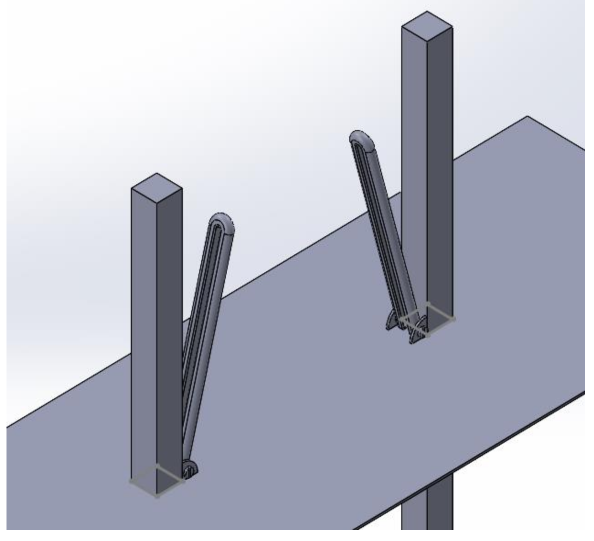


Fig. 12. SolidWorks of lock and standard gate.

The next design concept was drawn from the K-frame design and improves accessibility and comfort by having an expanding adjustable width. This adjustment could be implemented by either unlocking its fixed position with a mechanical key mechanism or be automatically implemented with electronic sensing and actuation. This could be done with either RFID input or an array of sensors to determine the approaching user.

Fig. 13 shows two arms pivoted at the base allowing for a change in width restriction further up the arms. For electronic actuation, a motor could act in one of three ways; rotation at the pivot of the arm (requires high torque), wind in a steel cable that draws the arm to the post, or similarly use a rack and pinion mechanism to pull the arm open.

Fig. 13 also portrays an entirely hands-free concept that would, in-theory, provide the easiest access through a gate requiring no additional arm movement besides driving the mobility scooter. By driving on or into paddles, a spring bolt would be drawn back, and the gate could be bumped open. With a large flexibility for input and linkage mechanism back to the latch, this design has a great amount of space for progression and testing.



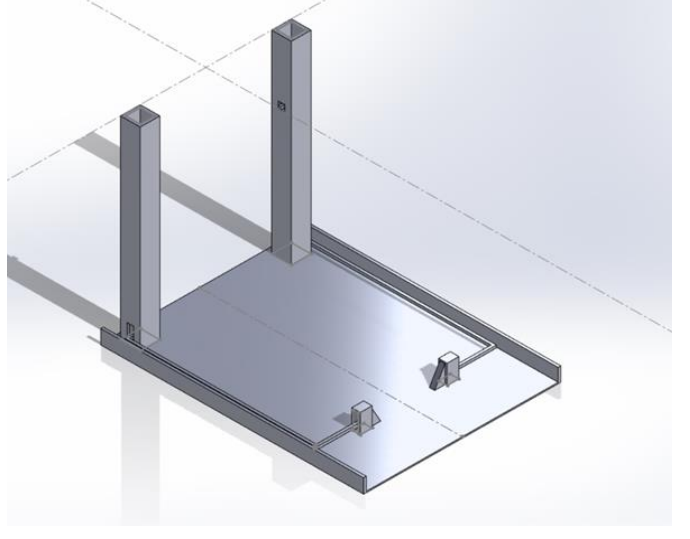


Fig. 13. SolidWorks of expanding K-frame gate (left) Mock-up SolidWorks of ride-on (right).

Fig. 14 shows a development idea on the RADAR kissing gate, with a key aim of making the lock more accessible. In this design, the restriction to gate leaf motion is achieved by an impingement at the hang post instead of the slam post – this is also where the locking mechanism is moved to. As a result, mobility scooters can unlock the gate with equal ease on both sides of the fence line. This all-mechanical design would help keep maintenance low compared to electronics, however, would require a more intricate lock and latch mechanism versus existing kissing gate designs, increasing costs and points of failure.

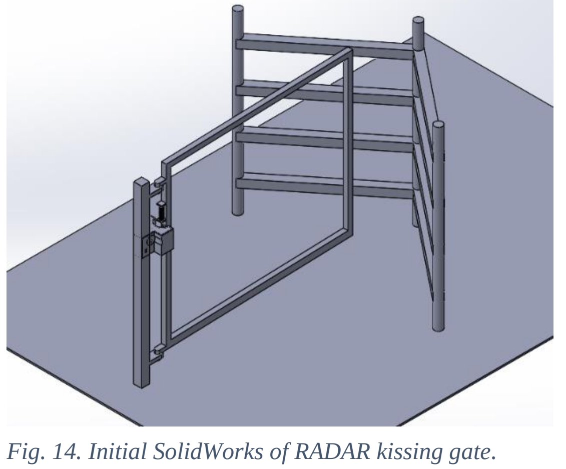


Fig. 14. Initial SolidWorks of RADAR kissing gate.

Table 3 lists the most interesting design concepts we considered, with their working principle listed beside them.

Table 3
Listing initial design concepts.

Design Title	Functional Principle	Appendix Reference
Expanding K-Frame	Using motor or locking mechanism to expand the restricting width	E.g Appendix B1)
Ride on mechanism	Drive on input to unlock gate latch and user pushes through	2
Hand crank RADAR lock	Hand operated crank draws back a latch inside the gate	3
Lever RADAR Key Lock	A pull-down lever drawing a steel cable connected to the gate latch. Lever secured in place by RADAR lock limiting to Disabled access only	4
Walking Stick/pole Key	Key shape or mechanism fitted to the end of a walking stick or pole assist to help reach a lock barrel from distance. Lock designed to be hard to tamper or replicate	5
RFID lifting pawls	Pawls holding gate strike in place lifted by motor actuation from RFID or sensor input, allowing for gate to then open	4
Motor Latch (standard 2-post)	Stepper motor driving a rack and pinion latch that draws in and out of the gate leaf/pawls	4
Induction Loop input	Using an induction loop to either sense the magnetic profile of the scooters (/motors), or the motorbikes and choose whether to open or lock the gate to suit	5
Pull up lever mechanism	Using a lever beside the driver that can be pulled up to release the gate latch. Similar concept to 'Lever RADAR Key Lock' with differing input and motion.	2
RADAR Kissing Gate with new lock mechanism	Relocated RADAR lock and latch mechanism to become more accessible to users. Changing lock position involves redesign of latch/ position limiting system	3

4.2. Design Matrix

After developing some of our initial ideas, we used a design matrix (seen in Appendix D) to evaluate them across different categories, and subsequently eliminate the lowest scoring designs. These categories and their assigned weightings were derived from the initial research we had conducted. For example, we knew that a self-closing gate design was imperative, to ensure stock-proofing, whilst also eliminating the need for mobility scooter users to lock the gate behind them – hence this was given the maximum weighting (5).

To judge the effectiveness of each design, we used the Aston 2-way gate as a benchmark to rank the designs against; the group had been informed at the COAT that the use of a trombone handle made it one of the most accessible structures, and had first-hand experience operating it. Moreover, to inform the score assigned to each design concept, we used feedback we had received from the questionnaire and LAFs to make evaluations. For instance, we had determined from our questionnaire that the overall perception of RADAR locks among the Disabled Rambler's community was largely neutral, hence designs that incorporated similar locking mechanisms were scored moderately in the 'ease for mobility scooters' category.

Once all of our design concepts had been ordered and critiqued, we drew out three designs that represented the best direction for the project. These were the 'RFID Kissing Gate', the 'Ride-on', and the 'RADAR Kissing Gate' designs.

4.3. Concept Development

To decide which of the three designs would be best for full-scale modelling, we first needed to develop the solutions in more detail, with either CAD or working scaled prototypes. Only then could we inform our decision on which design would be the most rewarding to demonstrate at full size.

4.3.1. RFID Kissing Gate

For an electronic solution, the consideration was made for the implementation of an RFID reader, operated via a fob system. We had been advised by LAFs that the issue of motorcycles illegally using footpaths was restricted to urban areas, hence it was assumed that in these locations there would be likely be access to mains electricity – potentially providing a power solution.

Upon detection of an input by the RFID reader, a motor is engaged, lifting the pawls, see Fig. 15. This action enables the gate leaf to be pushed forward by a mobility scooter user, as the strike on the gate leaf will no longer be latched. The gate is subsequently held open for a set duration, before the pawls are lowered again. Once the gate leaf is released, the rising hinges facilitate the return of the gate leaf to the latching point. Additionally, the pawls operate independently from the electronic lifting mechanism, enabling the self-closing functionality. This design allows the user to remain in the mobility scooter and operate the gate independently.

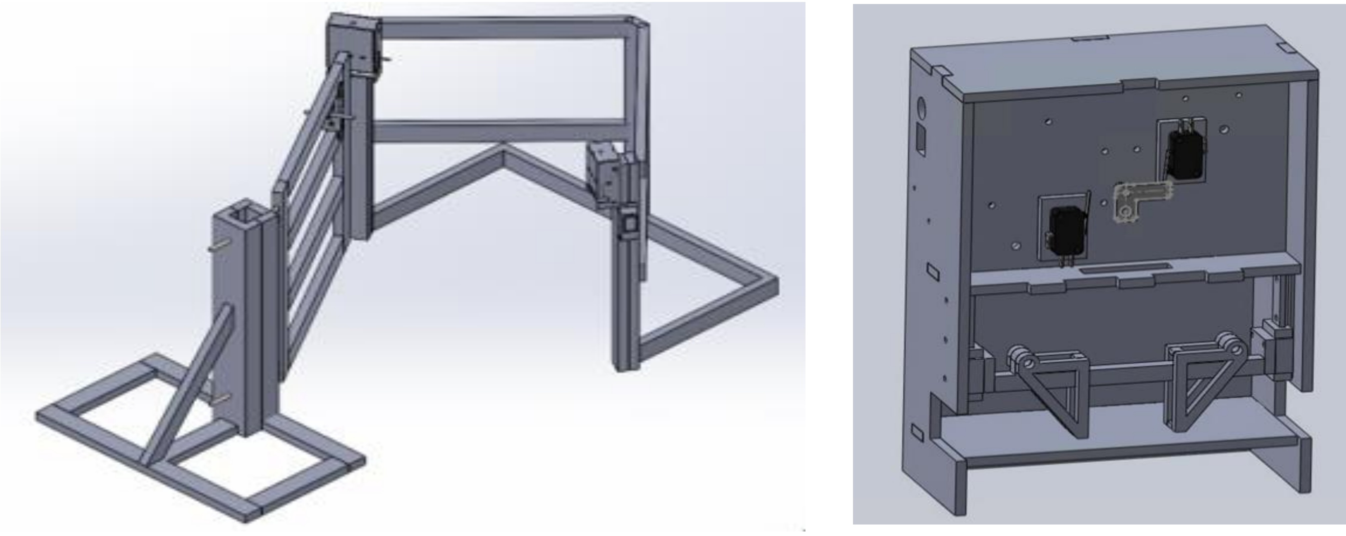


Fig. 15. SolidWorks of gate structure (left) and Pawl Housing (right).

Initially this electronic latching mechanism was designed to be incorporated with a pedestrian gate, however, this would have required the addition of stiles to accommodate able-bodied pedestrians. While this would keep access open to the most common and frequent users, it was advised during discussion at the *Disabled Ramblers Gates Workshop 4* that the introduction of stiles to accommodate foot traffic was not an appealing solution. Consequently, integration of the RFID concept with a RADAR kissing gate design was pursued to address these concerns. This modification necessitated alterations to the pawl housing design, resulting in the operation of two RFID-controlled latches in unison. Additionally, a RADAR padlock was also integrated into the strike, mirroring existing RADAR kissing gate designs. This feature served as both a manual fail-safe option while also accommodating users without the RFID fob.

Throughout the consideration of this design, we acknowledged the inconvenience associated with needing to carry an additional item - the RFID fob. However, we also noted that this is a pre-existing issue with RADAR kissing gates and RADAR keys. Furthermore, we also appreciated the potential issue of non-disabled individuals acquiring fobs, which also mirrored pre-existing issues with RADAR keys, and fell beyond the scope of our project.

4.3.2. RADAR Kissing Gate

The key principle of the RADAR kissing gate design was incremental improvement on existing design. Throughout the collection of research, we learned there may not be an ideal solution that solves all issues or fits all applications, therefore, any improvement on currently implemented gates would be a step in the right direction.

The RADAR kissing gate is widely regarded in the community as being disliked due to the poor ergonomics of the design, only being worsened by commonly poor installation. The positioning of the RADAR lock proves to ask a great deal from mobility scooter users, with our first-hand experience at the COAT centre as abled-body users not making the task any easier. Therefore, if the positioning could be improved, there is room for general experiences with RADAR kissing gates to become more positive.

The focus features of the kissing gate are the hang post, the gate leaf and the two strike posts. The gate (Fig. 16) uses a symmetrical layout with neither strike post lying on the fence line. This poses potential issues with hinge

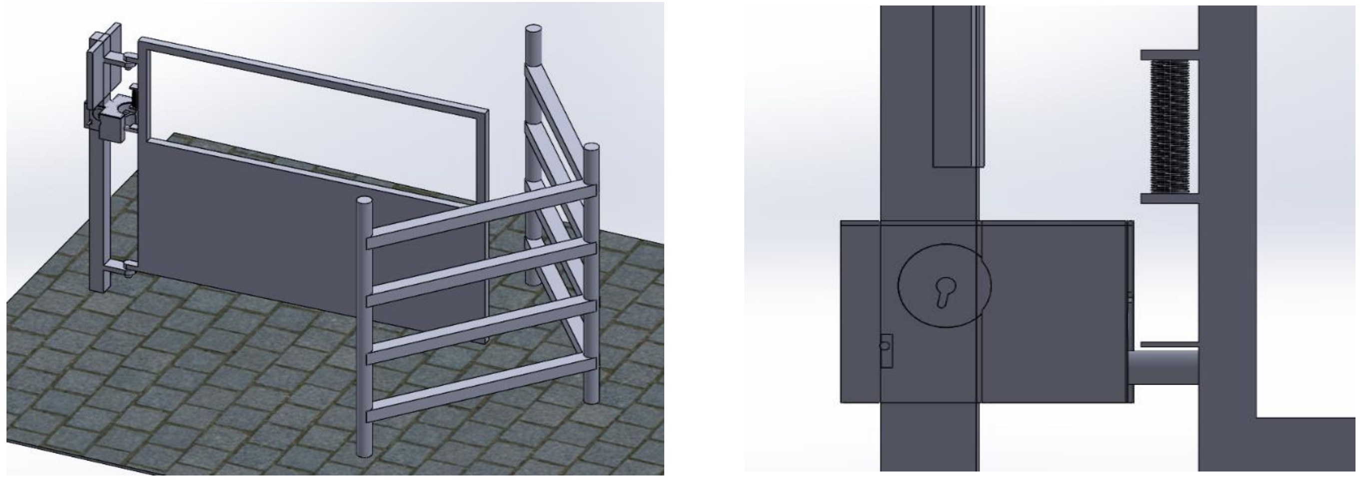


Fig. 16. Initial SolidWorks of RADAR gate (left) close-up of the SolidWorks for the lock (right).

choices and latching, as the rising hinges used in current kissing gate designs [11] return the gate leaf to a position where it would be unlatched.

The first step to developing this design was to decide on a more accessible location to implement the RADAR lock. By analysing the kissing gate structure, it was determined that the hang post is the easiest to reach area when approached from either side. This location choice also puts the mechanism in good proximity to the hinges, allowing it to be easily aligned. Following this, a mechanism was designed with a RADAR key input that allowed for mobility scooter access.

To help achieve self-closing, a new hinge design was developed (Fig. 17). The system uses a spring-loaded pin that is permitted to travel linearly up and down the gate leaf. By adjusting the spring's natural length, the force required to open the gate can be tuned to user preferences. Using this, the pin is pulled towards its resting position along the gate leaf's hang stile. Pairing this spring-loaded pin with an offset ramped slot created a self-closing mechanism that was skewed to align the gate leaf's resting position to a specific strike post (shown below in Fig. 17). This refinement addressed the hinge issues present in existing products.

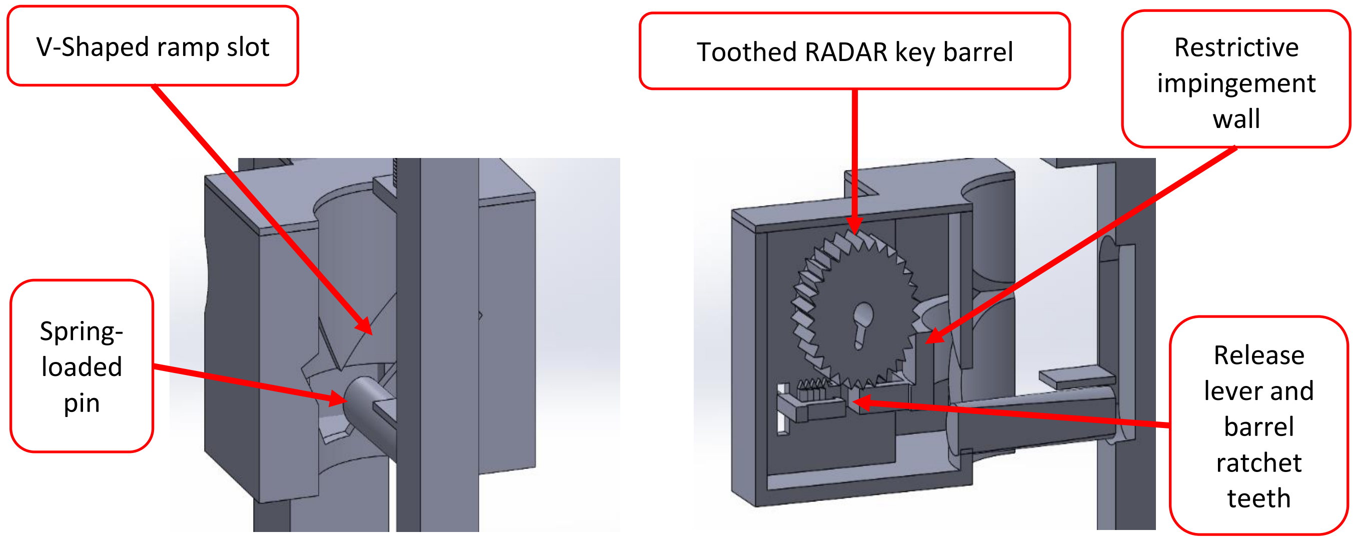


Fig. 17. Close-up of more detailed SolidWorks, front of lock (left) internals of the lock (right).

To limit the range of motion of the gate leaf for pedestrian access, impingements were introduced at either end of the slot used to guide the spring-loaded pin. These impingements are essentially walls that prevent the motion

of the pin outside a certain range. Therefore, if a user attempts to push the gate leaf outside of the allowed limits, the pin will collide with the impingements, preventing further motion.

After the impingements were addressed, the design could be adapted for use with a RADAR lock. In principle, the RADAR lock mechanism enables the hang post impingement to be disengaged, allowing the gate leaf to be swung through its full range. The locking mechanism was housed behind the slot in the hang post and was connected to the impingements via a toothed gear. When a user places a RADAR key in the barrel and turns it, the impingements retract out of the arc of the spring-loaded pin, providing increased range of motion of the gate leaf. The impingements are held in this position, since the gear teeth only turn in one direction - forming a ratchet. For the user to release this ratchet, and reset the mechanism, a small lever on the side of the casing is required. This represents an improvement on the current design, where users are required to lock a padlock.

One of the main advantages of this concept is that it aims to address the lock placement issue of RADAR kissing gates in a purely mechanical way. On the other hand, it is acknowledged that the mechanism is far more complex than the current sliding bolt design, thus it may involve higher manufacturing and maintenance costs.

4.3.3. Ride-on Mechanism

The aim of the ride-on design was to produce a fully mechanical, hands-free operated gate. This is achieved by exploiting the fact that all mobility scooters have at least one axle that has 2 wheels. There are several possible design routes: hydraulic plates the wheels can sit on, triangular wedges set on springs that the wheels slide to the side, and slats that the wheels push down on. For weighing up the possible options, the PDS criteria were consulted - mainly tamper-resistance. When considering this, the triangular wedges were deemed to be the best choice, as other options are more easily cheated.

The strength of the springs that load the wedges and the angle of the wedges is also used to deter motorcycle riders, as there is a significant weight difference between a motorcycle (80-90kg) and mobility scooter (140-160kg). This means that a motorcycle rider would have to attempt to manually push in the wedge with their foot whilst trying to keep their bike positioned on top of the other wedge.

The next major part of the ride-on mechanism is transferring the input force to the latch to open the gate. A few different ideas for this were formulated such as a rotating mechanical system (Fig. 18), sliding solid linkages (Fig. 19) or a pulley system (Fig. 20). After sketching each mechanism, it was possible to see the most points of failure occurring in a sliding solid linkage system, with three pins that could fail for every L-bracket, and every separate bar could also fail - although this is less likely. With regards to the rotating system, although it had the fewest points of failure, it was thought to be the most susceptible to debris jamming and blocking the pivoting bar. Due to these factors, a pulley system was selected for this part of the gate design, as the pulleys are available from many different suppliers with varying tolerances giving greater flexibility.

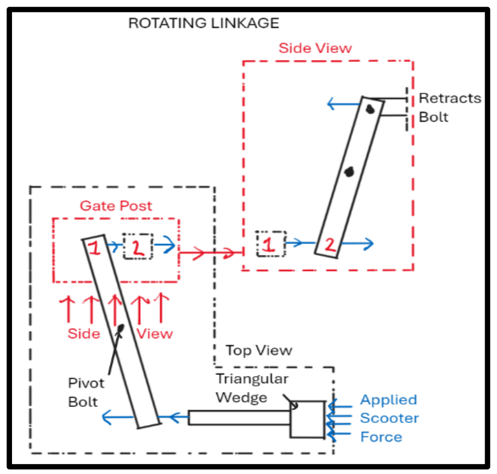


Fig. 18. Diagram of rotating linkage.

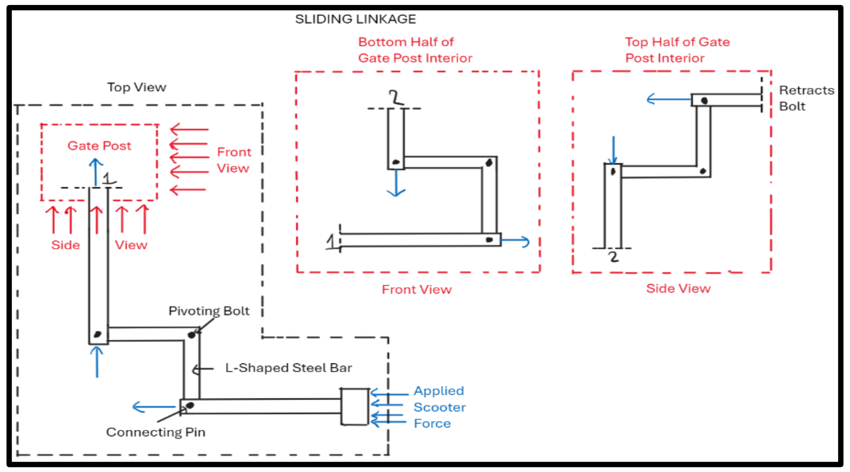


Fig. 19. Diagram of sliding linkage.

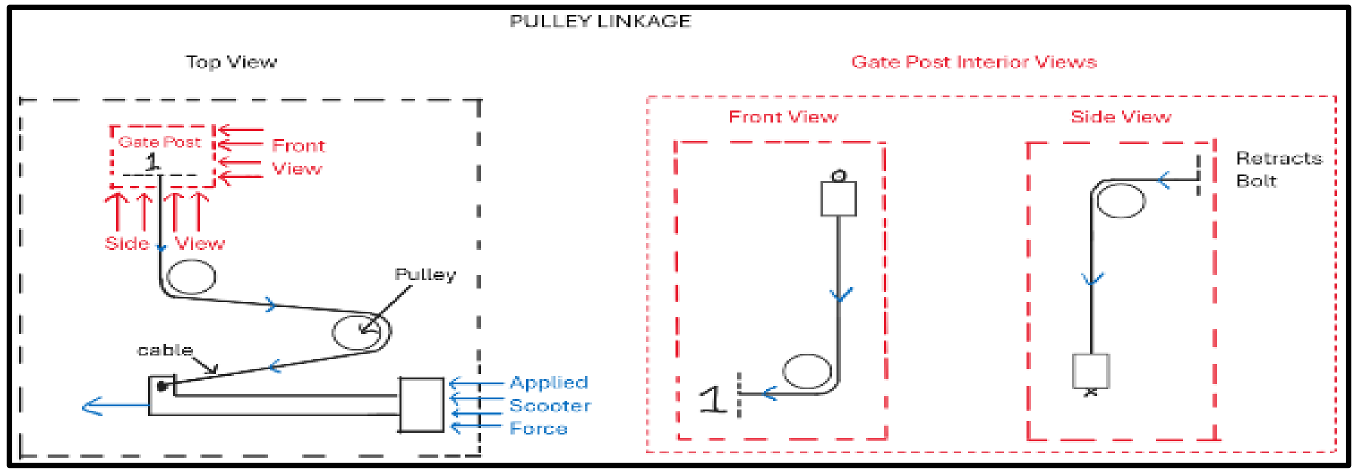


Fig. 20. Diagram of pulley linkage.

For the final part of this design, a mechanism had to be designed that would hold the bolt in the retracted position until a mobility scooter had passed through. There were two ways it was best thought to achieve this. The first one would be using an altered version of the stay-open latch so that it would be compatible with a bolt rather than a pawl. This stay-open latch shown in Fig. 21 was developed early in the project as a by-product of the visit to COAT and collaborating with the Disabled Ramblers. The design used interlocking metal teeth to keep the latch open that unmeshed when the gate slammed shut. This latch could be made from metal plates welded together and didn't require too high tolerances to operate. The second way was to order a pre-existing latch instead of custom building one. The one on the market that best suits our needs would be the type of latch used in car doors called FEBI BILSTEIN 17016 Door lock [12]. The way to get it to release is by pressing down a flange on the side of the lock. This could be done by having a setup where the open gate presses down on a lever that presses on the flange to release the bolt.

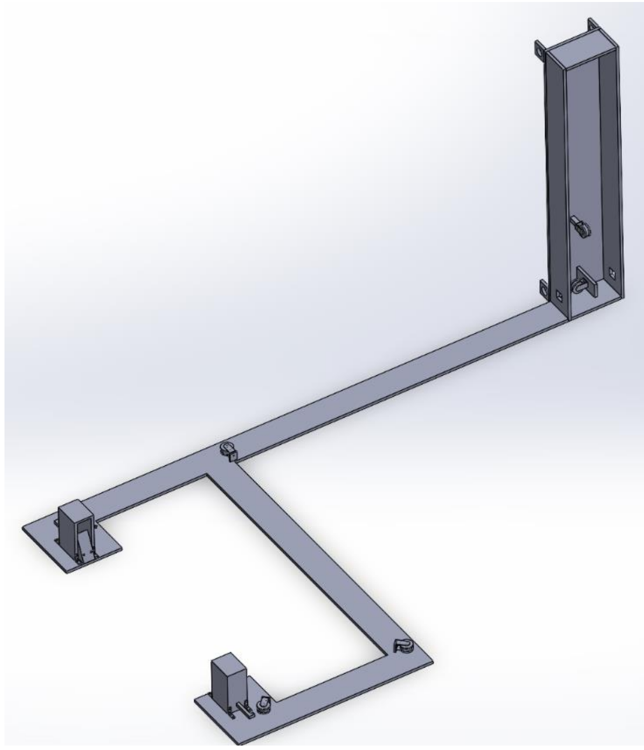


Fig. 21. SolidWorks for ride-on design.

Once mechanisms were determined, a SolidWorks model (Fig. 22) was created. Subsequently, required forces and spring stiffnesses were determined, such that the structure performed adequately. The properties used for the calculations are shown in Table 4, the equations used are shown in Appendix E whilst the results are displayed in Table 5. This highlights that a force of 381N is exerted on the steel cable, whilst a stress of 1MPa is experienced by the steel rod - which is far below the yield strength of mild steel (250MPa).

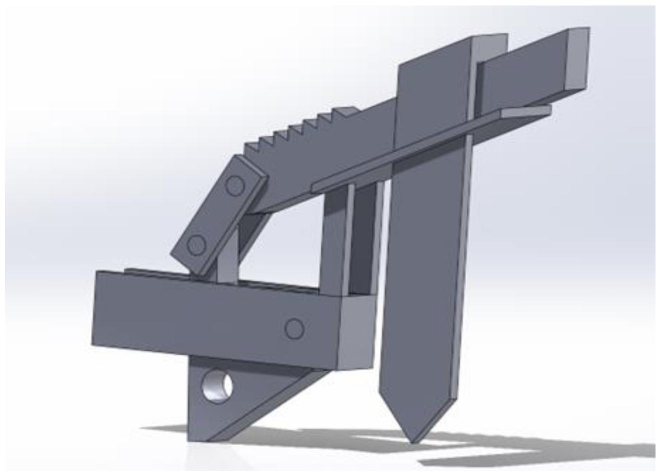


Fig. 22. SolidWorks of a stay-open latch concept.

Table 4
Input properties for force calculations.

inputs		
weight of person	70	kg
weight of mobility scooter	150	kg
number of wheels	4	
length of rod at input [L]	0.3	m
width/height of rod at input [H]	0.02	m
second moment of inertia [IM] of rod	1.33333E-08	m^4
assumed resistive force of the system	-	
material properties		
UTS	600	MPa
0.2% yield strength	410	Mpa
elongation	36	%
elastic modulus [E]	2E+11	Gpa
density	7900	Kg/m3

Table 5
Force calculations.

	value	unit	value	unit
angle of triangular wedge with ground [x]	45	°	0.785398	radians
total force on each wheel [F]	539.55	N	55	kg
downwards force [DF]	381.5194638	N	38.89087	kg
inwards force [IF}	381.5194638	N	38.89087	kg
axial loading (stress) of rod [AL]	953798.6595	Pa		
axial extension [AE]	1.4307E-06	m		
µ (used in eccentric loading)	0.378245686			
eccentricity [e]	0.02	m		
eccentric loading [EL]	-12473468.28	Pa	-12.4735	MPa
eccentric deflection [ED]	0.000129457	m		

4.4. Final Concept Selection

After updating the design matrix, only six points separated our best three designs (114-120), meaning the group were unable to come to a unanimous agreement on our final concept. Therefore, an anonymous vote was used to break the tie and move forward with the project. From the vote it was decided that the RFID kissing gate would be progressed.

5. Design of Final Prototype

5.1. Design Overview

5.1.1. Motivation for Design

Based on the existing designs we had seen, and feedback we had been provided, it was clear that manufacturing a completely mechanical structure that deters motorcycles whilst providing access for disabled users seemed to demand a level of complexity unseen on PRoWs today. After considering many ideas surrounding novel mechanical designs, we began to focus on how to improve existing structures on PRoWs that aim to deter motorcycles, whilst allowing mobility scooter access – the most fitting structure being the Woodstock Large Mobility kissing gate (made by Centrewire).

As previously discussed, the major issue with RADAR kissing gates in general is that mobility scooter users are required to reach the fence line to unlock the gate – often meaning that they must reach over their handlebars, causing severe discomfort for some, whilst being impossible for others. Therefore, the motivation for our chosen design was to move the unlocking mechanism away from the fence line, providing mobility scooter riders with a greater ease of use. We had seen a similar principle employed in the Broughton Moor gate (Fig. 3) and wished to incorporate a similar function within our design.

Unlike the Broughton Moor gate, RADAR kissing gates rely on a retractable shoot bolt to provide mobility scooter access, meaning the design could not be directly transferred. After searching for a completely mechanical solution to this issue, it was decided that using an electronic latch, such as that used in the 'Bump Gate', would be the simplest and most effective option. An illustration of our chosen design can be seen in Fig. 23 and engineering drawings shown in Appendix F.

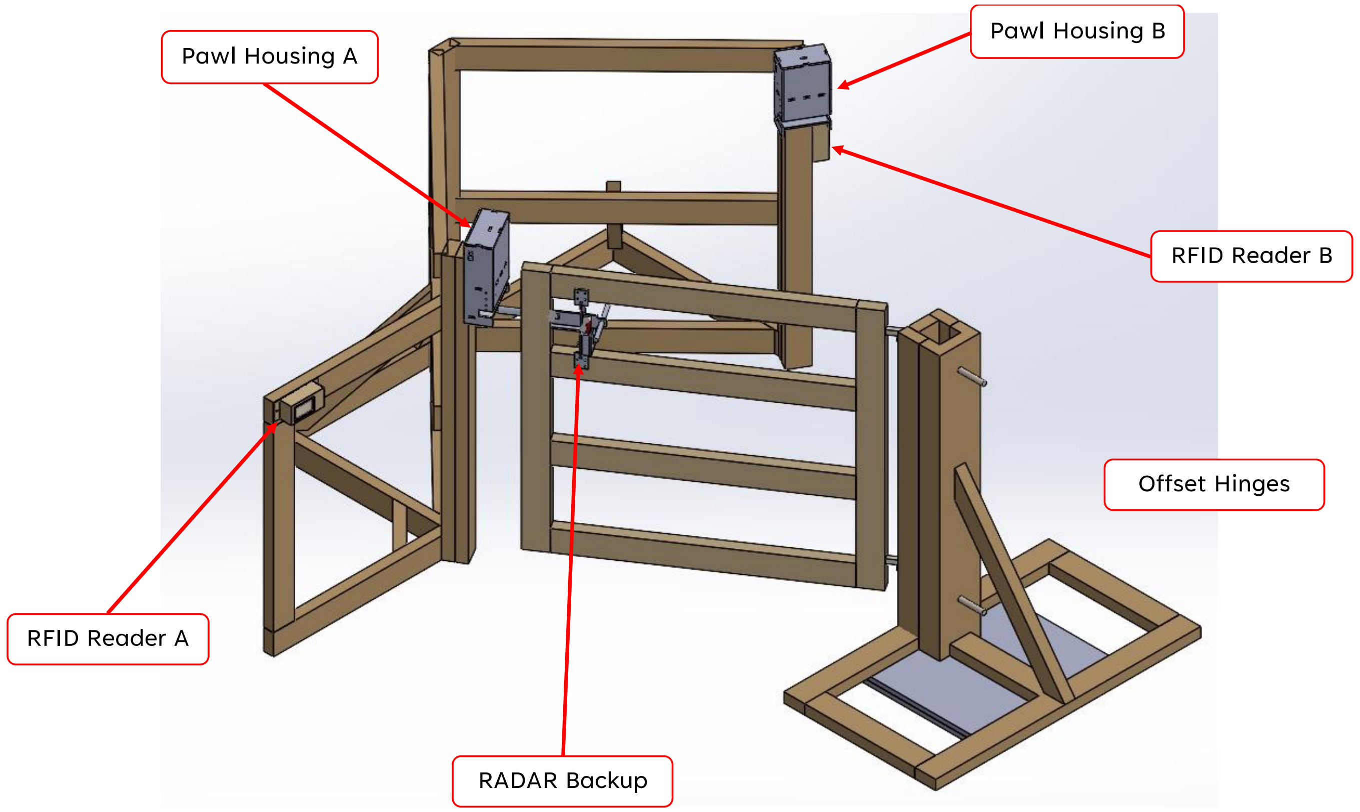


Fig. 23. Image of an overview of final prototype design.

5.1.2. Design Function

5.1.2.1. RFID Input

A key feature of our design is that the gate can be unlocked from a mobility scooter with minimal effort required from the rider. Therefore, we opted to use RFID readers, which would be mounted in easily accessible areas. These serve as an electronic substitute for RADAR padlocks, allowing the gate to be unlatched. Due to the structure of kissing gates, the gate leaf latches to one slam post of the enclosed area (side A in Fig. 24). When a user approaches the gate from side A, they are prevented from entering the enclosure by the gate leaf, which is latched. In our

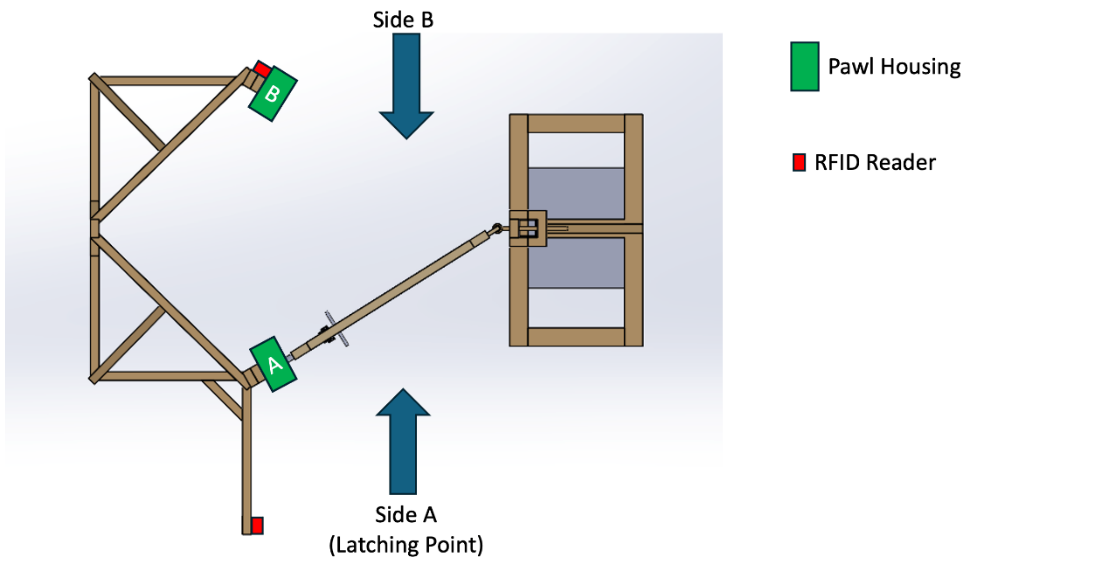


Fig. 24. Top-down view of structure with RFIDs attached.

design, an additional structure is used to create a mounting point for an RFID reader that can be accessed by a mobility scooter user approaching from side A.

On the other hand, when a mobility scooter user approaches from side B, they can enter the triangular enclosure, passing the other slam post along the way. This post provides an ideal location to locate an RFID reader, since it is tall and easily accessed from a mobility scooter seat. Attaching an RFID reader to this post eliminates the need to construct additional structures for RFID attachment, like that on side A, which reduces the weight and material cost of the gate.

5.1.2.2. Pawl Housing

Pawl housings are placed on both slam posts of the kissing gate, and are used to restrict the motion of the gate leaf, keeping it within the enclosed area. The pawl housing on side A acts as a latching point, ensuring the gate leaf is secure after each use.

5.1.2.3. Pawl Raising Mechanism

When approaching from side A, pressing a fob (with a valid ID) against the RFID reader will cause the pawls in Pawl Housing A and Pawl Housing B to be raised, allowing the user to drive their mobility scooter through the gate. Both sets of pawls need to be lifted, since the strike needs to be unlatched from Pawl Housing A, before the gate leaf can be swung through the enclosure, eventually passing through Pawl Housing B.

When approaching from side B, pressing a fob against the RFID reader will cause the pawls in Pawl Housing A to be raised. Both sets of pawls do not need to be raised, since the gate leaf is swung away from Pawl Housing B as the user passes through, and therefore, the strike does not need to pass through Pawl Housing B. Since only one pawl housing is operated, the gate requires less power.

5.1.2.4. Self-Closing

As previously mentioned, after a user has passed through a gate, the gate must self-close to ensure that livestock cannot escape. Our gate design aims to use rising hinges to return the gate to its resting position, such that the strike is within Pawl Housing A. Once enough time has passed to allow a user to pass through the gate, the pawls are lowered, allowing the gate to be latched.

5.2. Design Features

5.2.1. Latching Mechanism

The pawl housings we designed can be analysed in three compartments, namely:

- Pawls
- Crank-slider mechanism
- Electronics

Each of these compartments were designed to interact with each other, to make the pawl housings function as required. The locations of the compartments within Pawl Housing A are shown in Fig.25.

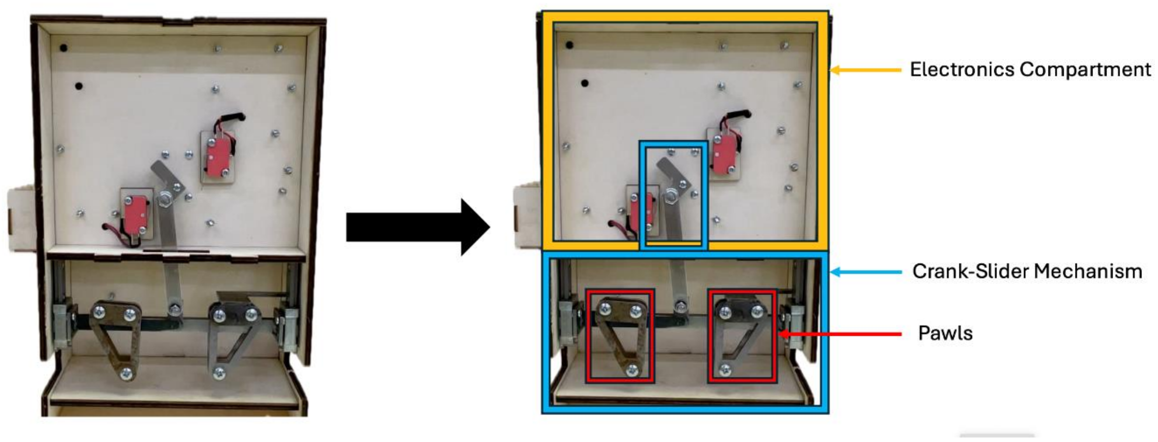


Fig. 25. Annotated image of Pawl Housing with electronics.

5.2.1.1. Pawl Design

Initially, we had planned to use the latching mechanism used in the 'Bump Gate' as a basis for our design (Fig. 26). Although appealing due to its simple design, small volume, and self-closing functionality, it was clear from testing our prototypes that the 'floating pawl design' did not function adequately. The biggest issue was that there was too much relative motion between the pawls and the lifting panel, causing the pawls to become jammed, such that they were unable to be lifted to allow the strike to re-latch. Tightening the tolerances of the design remedied this issue; however, it also increased friction between the pawls and the lifting plate, meaning that they were still unable to be lifted.

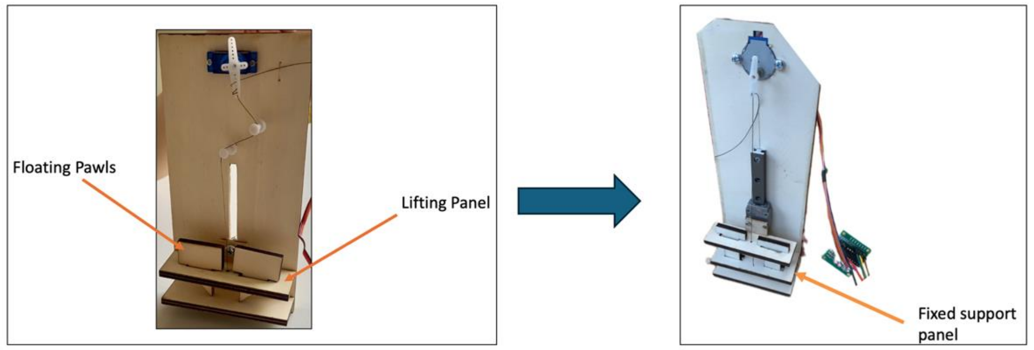


Fig. 26. Floating pawl design.

Considering this, a new design was introduced using a hinged pawl system, shown in Fig. 27, where one corner of the pawl is hinged to a lifting bar. While the hinged pawls have a larger and more complex design, the use of hinges means that the horizontal motion of the strike is easily translated into vertical clearance between the strike and the pawl.

To improve manufacturability and assembly of the pawl pieces and the lifting bar, the pawls and lifting bar were designed so that machine screws and locking nuts could be used to connect them, which allowed for simple installation and maintenance due to the removable, but secure, fixing.

Fig. 27. Evolution of hinged pawl design.

Furthermore, to accommodate for pedestrian access, one of the pawls in Pawl Housing A (latching point) was modified to incorporate a lever that protrudes out of the pawl housing. This functions as a means for a pedestrian to rotate the pawl and unlatch the strike, thus allowing movement of the gate leaf within the enclosed area.

Due to the high stresses experienced by the pawls when they are hit by the strike, it was decided that they should be constructed using mild steel, due to its high strength. The final pawl design is shown in the annotated Fig. 28.

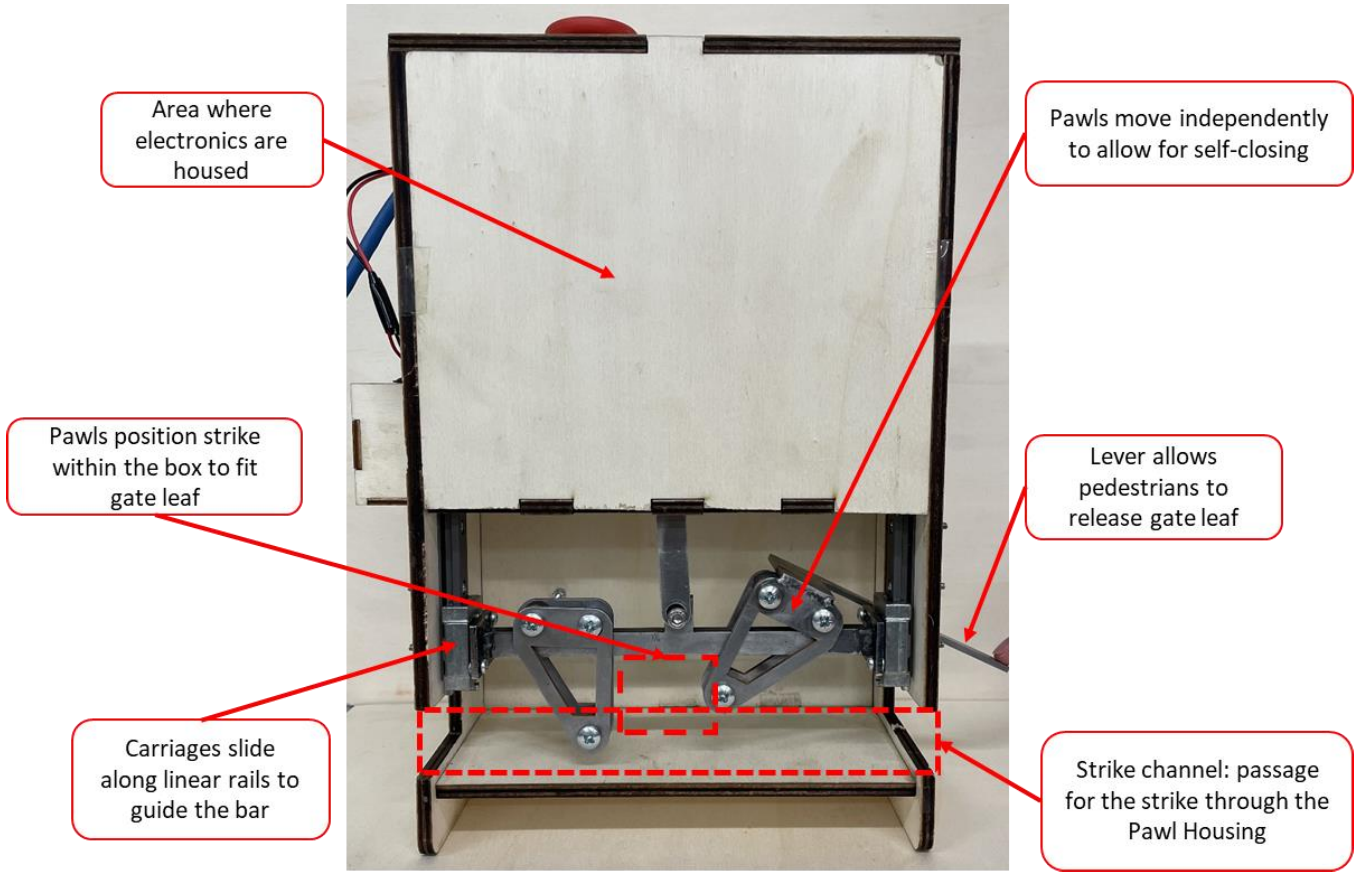


Fig. 28. Annotated image of features of the RFID box and pawl mechanism.

5.2.1.2. *Crank-Slider Mechanism*

5.2.1.2.1. Analysis of Mechanism

To raise the pawls (allowing mobility scooter access), we needed to find a simple, compact means of achieving vertical motion. Linear actuators are arguably the most appealing solution, since they are small and easy to implement, however, they are also significantly more expensive than motors - especially when high torque is required. Therefore, we narrowed our search to methods that achieve vertical motion only using motors, thus we needed a means of converting rotational motion to linear motion.

One of the most common ways of achieving this is using a rack and pinion design, with the teeth of the rack and pinion interacting, such that the rotational motion of the pinion is output as linear motion of the rack. Although we considered this possibility, we felt that it was not robust enough for use in a high stress environment, due to the potential for gear teeth to shear. Therefore, we looked for an even simpler solution, with less points of failure, and decided that a crank-slider mechanism was an ideal solution. Crank-slider mechanisms are possibly the simplest means of achieving linear motion, and hence, they are easy to design, analyse and repair – a key consideration for a structure that was designed to be used in a high stress environment. Fig. 29 depicts a schematic of the crank slider mechanism deployed in our design.

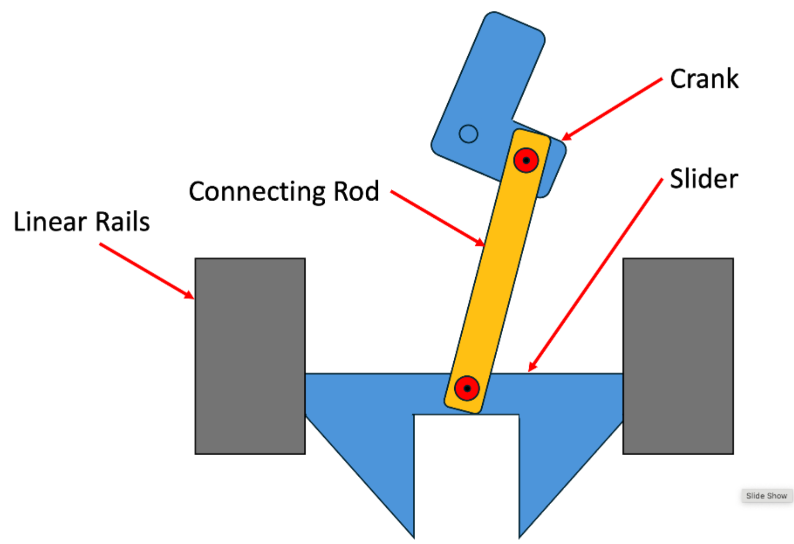


Fig. 29 Annotated image of pawl component.

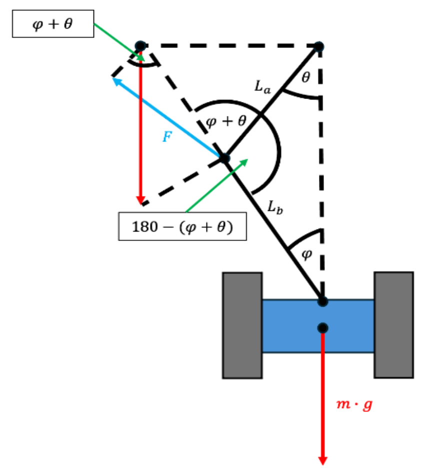


Fig. 30 Image of the forces and angles exerted on the pawl.

To determine the required torque for the motor, the stall torque of the system was analysed. Using Fig. 30 and equation 1, the stall torque of the motor, τ, can be determined as a function of the crank angle, θ and connecting rod angle, φ. It is assumed that the effects of the mass of the connecting rod, mass of the crank, and friction are negligible.

$$\tau = m \cdot g \cdot \cos(\varphi) \cdot \sin(\theta + \varphi) \cdot L_a \qquad \textit{(Equation 1)}$$

Where m is the mass of the slider, g is the gravitational field strength, and L_a is the length of the connecting rod.

Moreover, using equation 2, the stall torque can be expressed as a function of θ only.

$$\varphi = \sin^{-1}\left(\sin(\theta) \cdot \frac{L_a}{L_b}\right) \qquad \textit{(Equation 2)}$$

Where L_b is the length of the connecting rod.

Using the parameters in Table 6, the stall torque was plotted as a function of θ, allowing the maximum stall torque to be found for latch housing A.

Looking at Fig. 31, the maximum stall torque of the system is around 0.03 Nm, therefore, the motor selected for the design was required to have a substantially higher torque output than this value, to ensure that the slider could be raised.

Table 6
Table of parameters

Parameter	Value
m(kg)	0.4
g (m/s2)	9.81
L_a(m)	0.012
L_b(m)	0.084

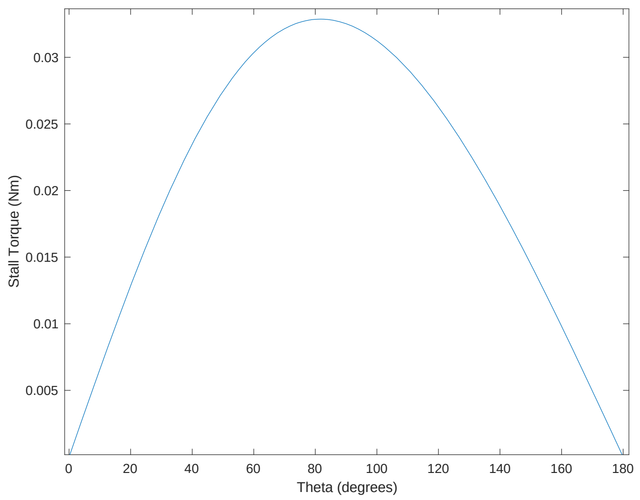


Fig. 31. Stall torque plotted against crank angle (theta).

5.2.1.2.2. Slider Components

To prevent lateral motion of the slider, a suitable method of fixation needed to be chosen. Initially, we attempted to use a single, central rail to guide the vertical motion of the slider, however, this proved to be too insecure, allowing the slider to be rotated around the point of attachment with the connecting rod. Therefore, it was decided that two linear rails should be utilised to eliminate unwanted motion of the slider. These rails were mounted at each end of the slider, such that the length of the rail was perpendicular to the length of the slider.

The linear rail we selected for this design was the Igus drylin® T guide rail TS-01, with compatible TW-04-12, T guide carriages. These rails and carriages were selected due to their high strength and corrosion resistance, allowing them to withstand high dynamic loads (up to 500N), whilst being unaffected in wet environments. Moreover, these rails and carriages were available to the group free of charge, thus did not reduce our budget.

5.2.1.3. *Electronics*

5.2.1.3.1. Determination Of Component Type

For the prototype to function as required, a suitable circuit needed to be developed. Table 7 identifies the required functions, and potential means of achieving them.

Table 7
Required functions and ways to achieve them.

Function(s)	Potential Solutions	Analysis of Potential Solutions	Reason for Selection
Determine state of circuit, and control components accordingly, store Master Key ID	Integrated Circuit (IC)	An IC is the only way to achieve the required function.	-
Read RFID fobs	RFID reader	An RFID reader is the only means of reading RFID fobs.	-
Determine position of slider	Encoder	• Provides precise positional control. • Limited selection of motors with in-built encoders.	To widen the range of options with reference to motor selection, limit switches were chosen to achieve positional control. Precise control of the slider position was not required, hence was not an important factor in the decision.
	Limit Switch	• Imprecise positional control. • Spatially inefficient. • Requires waterproofing. • Can be used to determine positions of systems using motors without encoders.	
Raise sliders to unlatch gate (linear motion)	Linear Actuator	• Provides linear motion, as desired. • Can be expensive, particularly when high torque output is required.	Purchasing a linear actuator with the required performance was too costly and therefore unjustifiable.
	Motor	• Outputs rotational motion, therefore, requires a means of transforming to linear motion. • Wide range of motors available.	
Transmit signals between multiple components over 4m distance	Bluetooth module	• No wired connection required. • Can transmit signals over 10m range. • Delayed signal transmission. • Multiple modules required to transmit multiple signals – can be expensive.	Using Bluetooth modules to transmit signal was too costly and impractical. Ethernet cables were chosen since they are more economical, whilst being easier to implement.
	Ethernet Cable	• Negligible delay in transmission. • Requires waterproofing. • Cheaper than Bluetooth modules.	
Notify user when gate is unlatched	Light	• Provides a visual signal to rider. • Low power consumption.	Realistically, both should be used, however, due to limited pins on IC, only a light was used.
	Buzzer	• Provides an audible prompt to the rider. • Low power consumption.	

5.2.1.3.2. Electronic Components Selection

After determining suitable component types, adequate products were identified, compared, and chosen. This process is summarised in Table 8.

Table 8
Process of comparison and selection of components.

Component Type	Options	Price per unit (£)	Analysis of Option	Reason for Selection
IC	Arduino UNO	25.00	• Low cost. • Easy to program. • Readily available.	Although it was desirable to use a smaller IC, the Nano ESP32 has an insufficient number of I/O pins. Furthermore, the group already had spare Arduino UNOs, so they could be used without reducing the budget.
	Arduino Nano ESP 32	19.98	• Low cost, low power IC. • Easy to program. • Significantly smaller than UNO. • Fewer I/O pins compared to UNO - fewer components can be controlled.	
RFID reader	MFRC-522 module [13]	5.59	• Significantly lower cost than UART readers. • SPI interface not suitable for transmitting signals over long distances (5-10m limit).	Due to significantly lower cost, MFRC-522 module was chosen for prototype. Despite range limitations, the module is still capable of transmitting signals over the required distance.
	Eccel Technology Ltd Pepper-C1-UART RFID Reader [14]	40.40	• Allows for transmission of signals over longer distances due to lower transmission losses.	
Limit Switch	Micro Limit Switch Short Straight Hinge Lever [15]	1.33	• Lever allows switch to be triggered by a rotating object.	For this prototype, functionality was one of the most important considerations. Since both options have nearly identical functions, cost was the deciding factor.
	Omron Hinge Lever Limit Switch	1.42	• Lever hinged, as the above option. • IP40 rated.	
Motor	Turbo Metal Gear Worm Motor [16]	18.10	• Higher torque compared to stepper motors. • Worm gear prevents back-driving. • No power consumption when stationary due to worm gear. • 1 Nm stall torque	An important feature of our design was that it needed to be tamper-proof – therefore a motor that couldn't be back-driven was selected.
	NEMA 17 Stepper motor [17]	12.00	• Precise positional control • High power consumption when stationary • 0.2 Nm stall torque	
Motor Driver	IRF520 MOSFET driver [18]	5.99	• Smaller than L298N. • Suitable for selected motor	There is no requirement to run the motor in reverse, therefore, H-bridge is not necessary. Due to the limited space within the Pawl Housing, the IRF520 was selected for its smaller profile
	L298N dual H-bridge driver [19]	3.50	• H-bridge allows motor to be reversed • Requires heatsink • Cheaper than IRF520 • Suitable for selected motor	

5.2.1.3.3. Wiring

The Arduino UNO was used as a state machine to ensure that the gate functioned as intended and at the right time. To determine which state to proceed to and when to proceed, the Arduino took inputs from the RFID readers and limit switches. The pin connections used by the Arduino are shown in Table 9.

An explanation of the pin connections and wiring is provided below:

- Ethernet cables were used to connect the readers to the Arduino (connected via RJ45 connectors).
- To synchronise the communication between the Arduino and the RFID readers, they were wired in a serial peripheral interface (SPI) bus, sharing MOSI, MISO, SCK and RST lines.

Table 9
Pin connections used by Arduino.

Arduino Uno Pin	Input/Output (I/O)	Connections
Digital 5	O	Driver A Signal
Digital 6	O	Driver B Signal
Digital 8	O	RFID Reader A SDA
Digital 9	O	RFID Reader A/B RST
Digital 10	O	RFID Reader B SDA
Digital 11	O	RFID Reader A/B MOSI
Digital 12	I	RFID Reader A/B MISO
Digital 13	O	RFID Reader A/B SCK
Analog 0	I	Limit Switch A1 NC
Analog 1	I	Limit Switch A2 NC
Analog 2	I	Limit Switch B1 NC
Analog 3	I	Limit Switch B2 NC
3.3V	-	Reader A/B 3.3 V
5V	-	Limit Switch A1/A2/B1/B2 COM
GND	-	All GND pins, pull down resistors

- Motor drivers were connected to PWM pins on the Arduino, such that their speed could be controlled; if the motor speed wasn't moderated, they could have posed a safety risk.
- The normally closed (NC) terminals of the limit switches were wired to the Arduino via pull down resistors (100 kΩ). Thus, when the limit switches were pressed, the input pin on the Arduino was pulled to ground, reading a digital low voltage.

The circuit diagram is shown in Fig. 32.

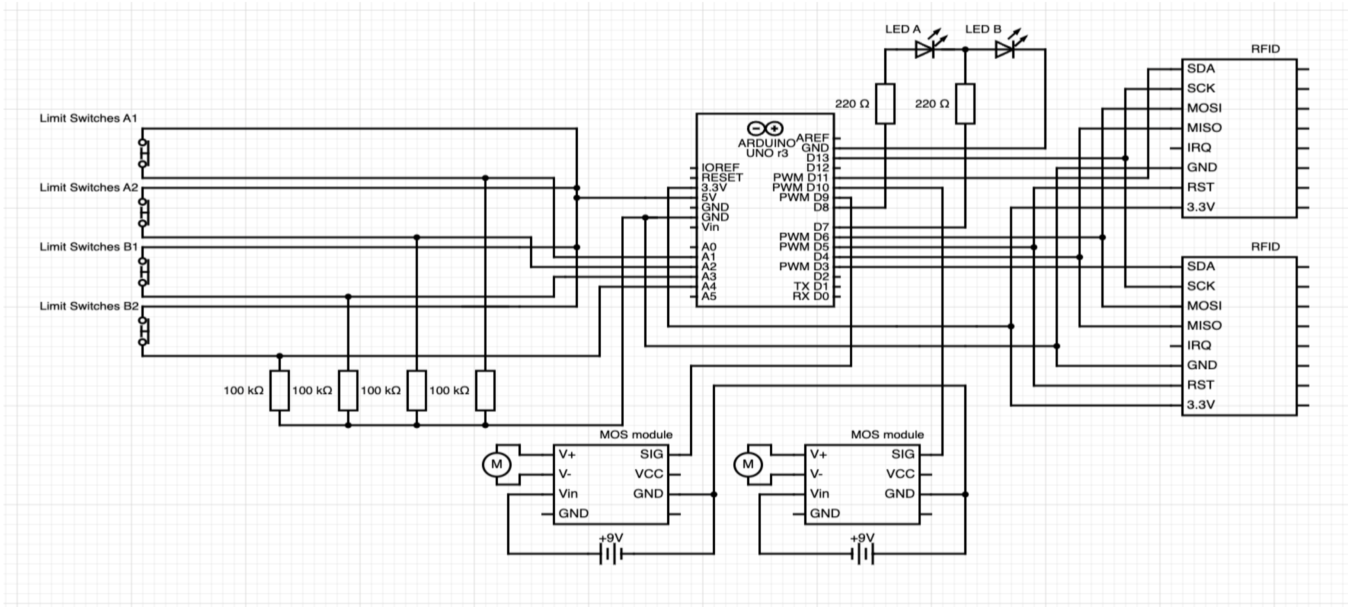


Fig. 32. Circuit diagram for latching mechanism.

5.2.1.3.4. Electronic Components Layout

One of the main concerns with the use of electronic components is reliability, particularly when exposed to harsh, outdoor environments. Therefore, decisions around the location and attachment of the electronic components were informed by ease of waterproofing, maintenance, and assembly.

Due to the impact imparted on the pawl housings by the closing gate leaf, it was decided, where possible, electronic components should be attached by nut and screw, such that they were secure but also removable in case of damage. Moreover, to prevent water ingress, it was judged that none of the electronics should be screwed to external walls. From these two conclusions, it was reasoned that a large internal wall should be used to mount all parts to. Furthermore, for ease of maintenance, this internal wall was designed to be removeable, such that damaged parts could be replaced easily. The layout of the components on the removable board in Pawl Housing A is displayed in Fig. 33.

5.2.1.3.4.1. Pawl Housing A

Looking at Fig. 33, the Arduino, MOSFET driver, DC motor, stripboard and RJ45 connectors were located on the back of the removable panel in Pawl Housing A. Conversely, the limit switches were positioned on the front of the removable panel, either side of the motor shaft. This was so the limit switches could interact with the crank to determine the position of the slider.

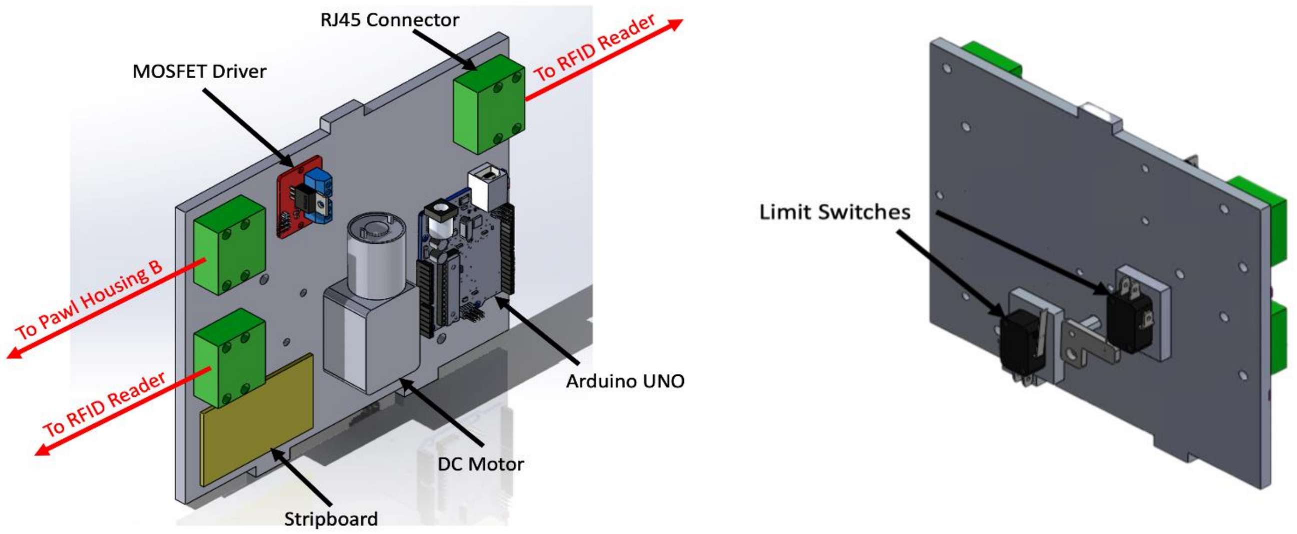


Fig. 33. SolidWorks of the back of electronics panel (left) and front of panel (right).

To facilitate this interaction, the crank was shaped so that it had a protrusion on one side, forming an L-shape; as the motor turned, the protrusion would hit the arms of the limit switches. When pressed against the limit switch on the left side of the shaft, the slider was fully raised (Fig. 34).

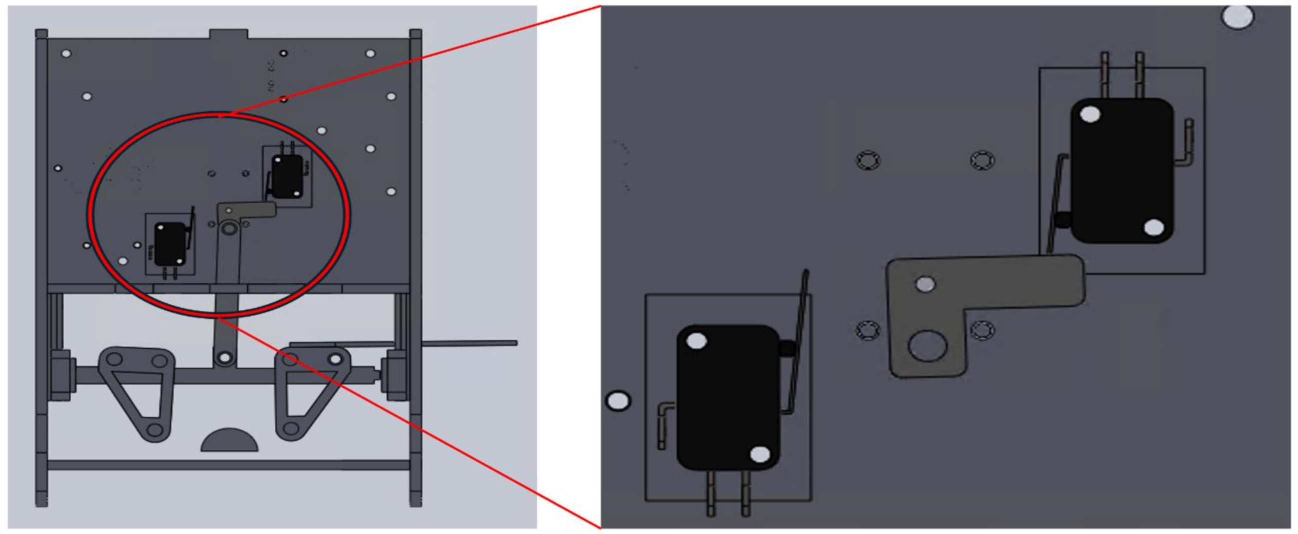


Fig. 34. SolidWorks of crank position when slider fully lowered.

When pressed against the limit switch on the right side of the shaft, the slider was at its lowest point (Fig. 35).

The same crank design was also adopted in Pawl Housing B.

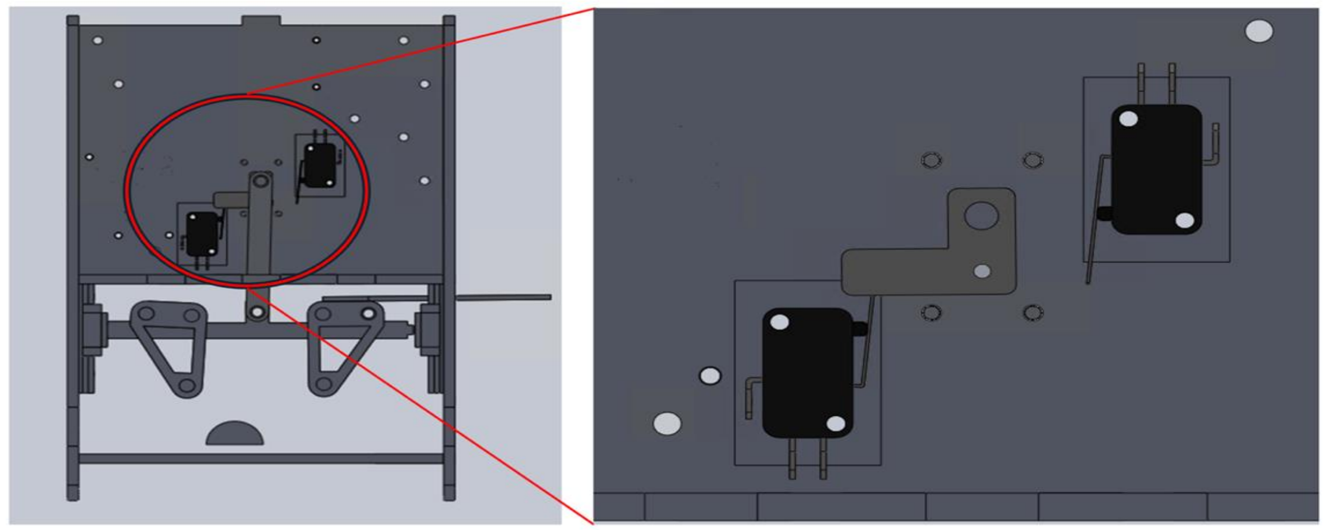


Fig. 35. SolidWorks of crank position when slider fully raised.

5.2.1.3.4.2. Pawl Housing B

Despite being located around 1.5m away, the operation of Pawl Housing B was controlled by the Arduino in Pawl Housing A. Therefore, for Pawl Housing B to function, signals needed to be sent to and from the Arduino:

- 5V was required by the common (COM) terminal on the limit switches.
- Output voltages of limit switches needed to be monitored.
- A PWM signal needed to be sent to the driver.
- A ground line was required.

Since the housings were not local to each other, an ethernet cable was used to transfer the signals between the two. The layout of the electronic components in Pawl Housing B is depicted in Fig. 36.

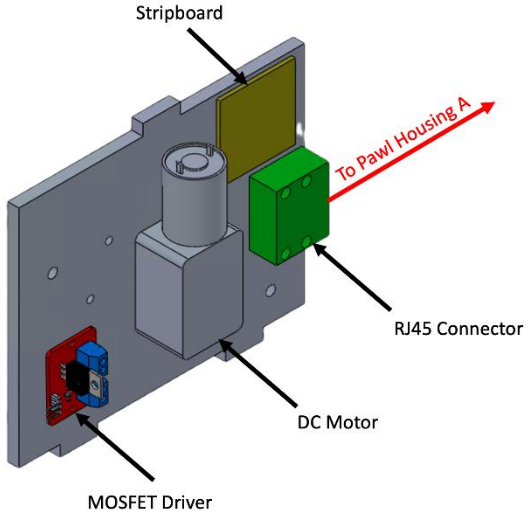


Fig. 36. Electrical component layout in Pawl Housing B.

5.2.1.3.4.3. RFID Housings

The RFID readers were positioned in ergonomic locations (further discussed in section 5.2.3.2), separate from the latch housings. A small casing was constructed to house the reader, LED and RJ45 connector. The flanged back-plate of the casing provided an attachment point to mount the casing to the gate frame. This design is depicted in Fig. 37.

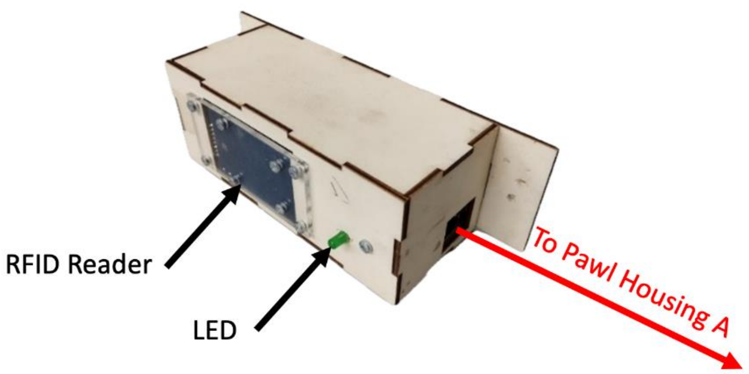


Fig. 37. RFID reader housing design.

5.2.1.3.5. State Machine

As mentioned, to ensure that the gate performed as required, a state machine was developed. The state machine had several key features, which aimed to provide ease of use to the user, whilst also limiting the power consumption of the gate itself.

Fig. 38 shows the different states that were occupied by the Arduino. Looking at Fig. 38, the machine entered separate cycles depending on which RFID reader was triggered. When approaching from side A, both sliders were lifted, since the strike needed to pass through both pawl housings as the user pushed the gate leaf. On the other hand, when approaching from side B, only the slider in Pawl Housing A needed to be lifted. In this instance, less power was drawn by the system, improving energy efficiency.

Another feature of the state machine was the implementation of a delay state, which held the gate open for a set duration. Once a user presented their fob, and the gate opened, they were given a set amount of time to pass through the gate before the sliders were lowered. One prominent piece of feedback that we received from mobility scooter users was that some gates do not stay open for long enough to allow them to pass through comfortably, thus it was important to address this issue in our design.

This state machine was replicated within the Arduino integrated development environment (IDE). The corresponding script can be found within Appendix G.

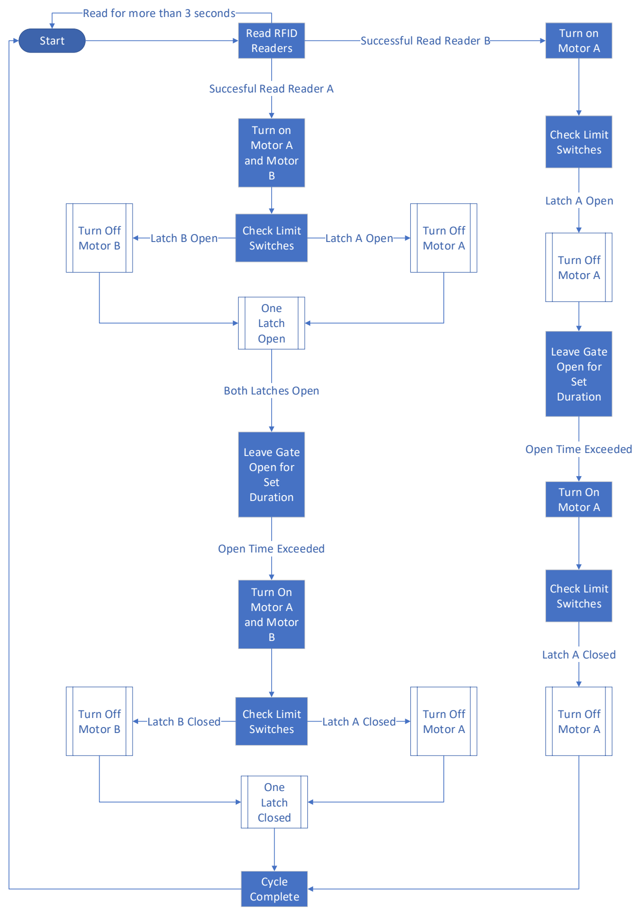


Fig. 38. State machine flow chart for latch operation.

5.2.2. Gate Leaf

5.2.2.1. RADAR Strike/Shoot-bolt

In the scenario the electronics fail, it is imperative that the user can still travel through the gate. This is why it was decided to make the latch strike a retractable shoot-bolt. To ensure this feature is only utilised by the desired parties, the well-established RADAR lock was implemented to restrict the motion of the shoot-bolt as shown in Fig. 39. This essentially allowed the gate to be used like a conventional RADAR kissing gate.

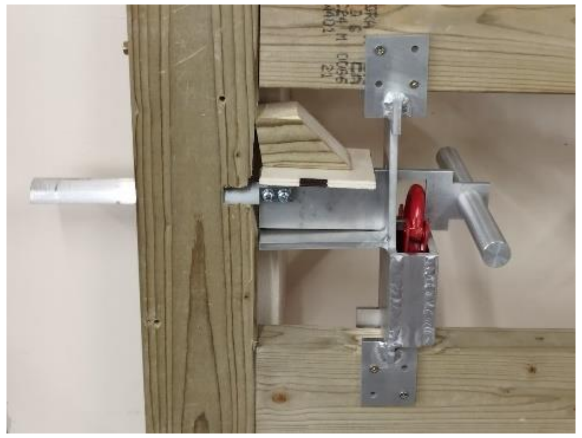


Fig. 39. Manufactured strike and RADAR latch.

Fig. 40. Image of RADAR lock and key.

Fig. 40 shows a simple RADAR padlock and key that was purchased for use in the gate. Once the product was in hand, sizing and designing both the shoot-bolt and its mounting bracket was relatively simple. Positioned at the end of the gate leaf; lightweight aluminium was the ideal material choice to provide rigidity, whilst also limiting the moment that the free-standing structure would have to counteract. Although functional, the padlock housing was found to be loose. With design tolerances being too great, material was packed both underneath and beside the lock, securing its position whilst ensuring the keyhole and padlock arm were both unimpeded. With the holder finalised, it was incorporated into a mounting bracket that fixed the shoot-bolt and RADAR lock onto the gate leaf.

Fig. 41 displays the final manufactured bracket produced from 6mm aluminium. The design was waterjet cut and welded using the university facilities and features an array of 5.1mm holes that permit wood screws to secure into the timber gate. These holes were positioned on rectangular plates spaced with 2mm clearance for our 45mm timber thickness. A flat plate protrusion was added to the back of the bracket to support the linear motion of the shoot-bolt, aiding alignment.

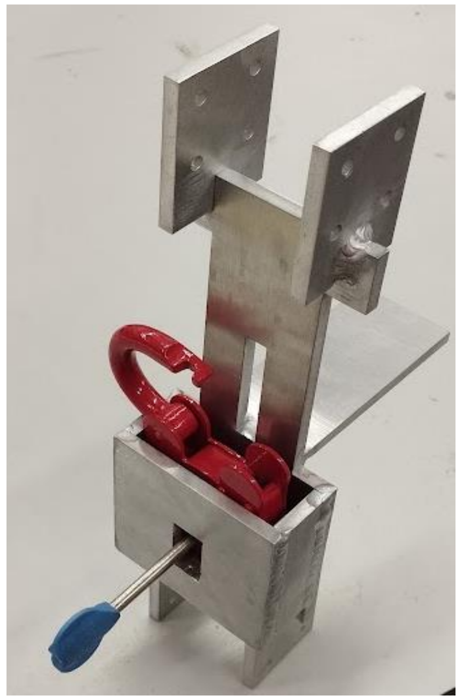


Fig. 41. Bracket with RADAR lock in place.

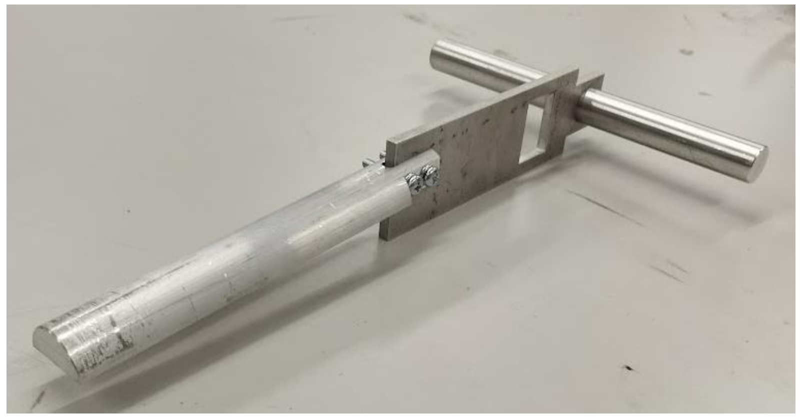


Fig. 42. Final manufactured shoot-bolt design.

Typical shoot-bolts feature a circular profile; however, as seen in Fig. 42, for our chosen design we opted for a semi-circular profile. This allowed us to reduce the height of the strike channel on the pawl housings whilst maintaining strength in the direction of impact on the strike. Minimising the height of the strike channel was seen as a desirable feature, as it limited the space available for objects to be inserted into the pawl housing, such that it was more difficult to manually lift the pawls. To construct this component, we used a 6mm plate featuring an opening (for passage of the RADAR padlock arm), attached to a 16mm aluminium rod (providing a handle for users to draw back the strike).

5.2.2.2. Rising Hinge

A self-closing feature is a requirement of most existing gates. If a gate does not self-close, it can be moved under wind loads, potentially causing it to swing at high speeds, posing a significant risk to pedestrians. Moreover, for stock proofing, a self-closing feature ensures that the gate is always closed after use, preventing livestock from escaping.

In general, two solutions are employed to achieve self-closing: modified door closers and self-closing hinges. The two solutions are significantly different, and therefore have different use cases.

Door closers represent a mass-spring damper system, allowing self-closing to be achieved, whilst the speed of closure and time to close can be tuned. Larger gate leafs (such as those used on bridleways) close with more force, hence require some damping to prevent the gate from slamming into the fencepost and potentially causing damage. These modified door closers are quite expensive, and therefore are not used universally.

The gate required a self-closing hinge set capable of a 180° opening span. A suitable model was found through the Centrewire gate manufacturer, and consulting with the company helped us understand its principal operation. These hinges, seen and understood in Fig. 43, would be mounted directly into the wooden gate post using both a threaded clamping mechanism for the top ‘hook to bolt’ hinge, and two threaded screws for the base ‘hook to plate’ hinge.

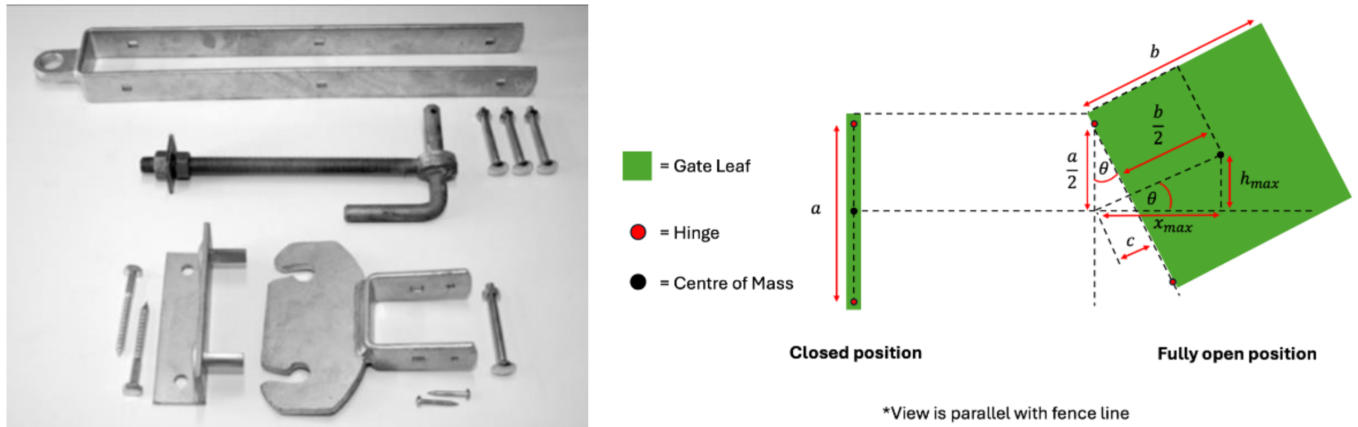


Fig. 43. Image of self-closing hinge pieces (left), diagram of how self-closing hinges operate.

Using an offset of the gate leaf’s centre of mass, the hinges are designed to cause the gate leaf to rise or fall relative to its initial position. Therefore, the gate naturally wants to swing to the lowest position in its arc and return to the resting position functioning like a form of pendulum.

Although, the hinges are designed to return to a 90° position in its 180° span, our kissing gate would be advantaged by a resting position of 60° or 120°. This is due to the positions of the pawl housings being arranged at these angles. If the hinges were to align to a gate post at one of the two angles, the design would be able to produce precise and repeatable results in its relatching function.

To try and achieve this, we attempted to change the alignment between the top and bottom hinge hooks. Although the alteration did show signs of allowing the gate to rest at a new angle, the gate was instead able to rest in a large angular window, meaning the gate lost both predictable resting position and sensitivity for its ability to self-close.

With the testing showing no reward, we decided to model using the standard hinge position and focus on the principal operation of the electronic latching pawls. If these pawls proved both functional and robust, then a newly developed hinge in the future would improve this design greatly. This is not the only issue with the current hinge’s function; the rising and falling of the gate leaf requires the pawl housings to be mounted at an angle, such that the strike channel can accommodate the passage of the strike.

5.2.3. Free -Standing Structure

Material choice in the final prototype consisted mostly of treated timber for the main structure, with a select few metal mechanisms being added. The selection of wood for the majority of the design was done for a few reasons. The first being, wood is far easier to work with and cut - this allowed the gate to be manufactured by the group. If metal was used more widely it would have required a lot more EDMC involvement, which would have created

large delays. Wood is also more sustainable to source than steel if it is for the purpose of a one-time use. Additionally, cost was a major factor in choosing wood, as we paid £1.03 per kg of wood, whereas steel from the EDMC would have cost us £2.67 per kg.

5.2.3.1. Hang Post & Base Plate

The hang post is a central structure to any gate frame, due to the static and dynamic loads it experiences via its attachment to the gate leaf. Since we did not have a permanent location to test our design, we were required to construct a free-standing structure. We initially considered using a 200x200mm profile with a solid wooden post; however, this solution was deemed to be too expensive, so we explored alternate methodologies.

It was concluded the post profile could be replicated from the same timber profiles we used to construct our gate's frame. Arranging the 45x95mm timber in the formation showed in Fig. 44, a new hollow post could be constructed with only a fractional reduction in profile. The hang post would see a reduction from 200x200mm down to a 185x190mm profile, leading to a reduction in weight that aids in transportation. This new post design was chosen and constructed with M8x120mm screws, seated in bored holes to both get further penetration into the material, and position the screw heads, such that they did not protrude. With timber being ordered in 3600mm lengths, it was natural to choose a post height of 1200mm. In comparison to the Woodstock Large Mobility kissing gate, there was an 100mm increase in overall post height.

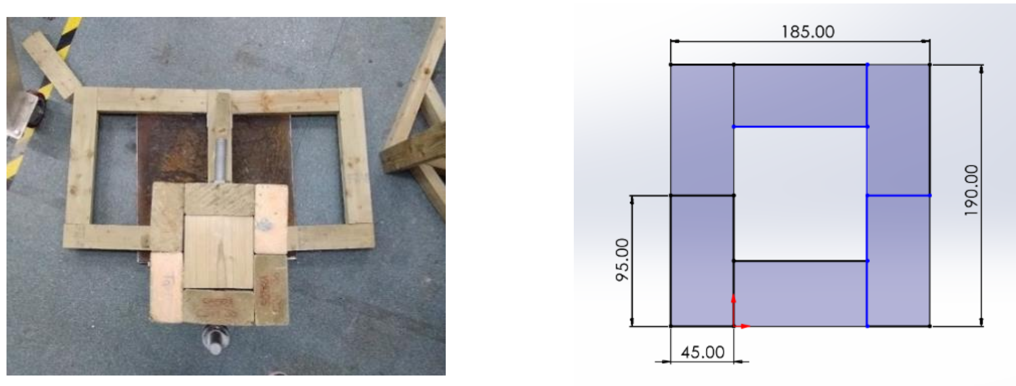


Fig. 44. Alternative post construction (left), dimensions for post (right).

To help counteract the moments caused by the gate leaf, several options were explored. Initially, the method of choice was creating a rectangular wooden base-frame fixed to the post, which would have weight loaded upon it. This would prevent tilting of the post in three directions, as the base-frame would be seated flush with the floor

Fig. 45. Final construction of the hang post.

and supported with angular braces. However, we determined that this method induced significant stresses in the brace's fixings, which would likely fail. The constructed wooden base-frame is depicted in Fig. 45 below.

Instead, the idea of a steel base plate with a welded post was proposed. This method involved taking advantage of the hollow profile of our gate post and installing a second shorter steel profile inside the taller timber feature. This steel post was welded to a 20mm thick steel base plate and distributed the reaction force across a larger area of the 100x95mm cavity in the post - reducing the likelihood of material failure.

To ensure the base plate was heavy enough to counteract the full magnitude of the moment, additional metal plates were utilised; featuring a bore that was scaled fractionally larger than the profile of the post, allowing the plates to be overlaid atop the existing welded plate. With this strategy decided, a calculation was performed to investigate the number of plates that would be required.

Table 10
Parameters for supporting plate calculations.

Symbol	Value	Description
Mw	22.5Kg	Mass of gate leaf
Mn	1.2Kg	Mass of RADAR latch
Mc	16.1Kg	Mass of Wooden post base-frame
Ms	?	Required Combined mass of steel plates
L1	800mm	Distance from centre of post to gate leaf centre of mass
L2	1100mm	Distance from centre of post to RADAR latch centre of mass
L3	372.5mm	Distance from centre of post to base-frame centre of mass
L4	217.5mm	Distance from centre of post to steel plate centre of mass

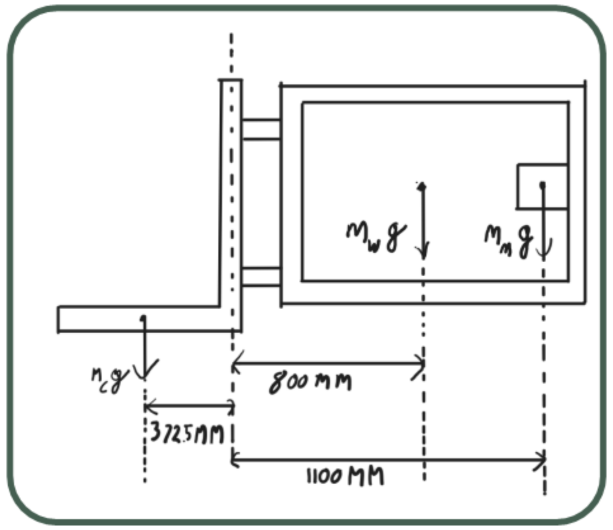


Fig. 46. Diagram of forces on gate leaf.

Using moment equilibrium:

$$(M_w \times L_1) + (M_n \times L_2) = (M_c \times L_3) + (M_s \times L_4) \qquad \text{(Equation 3)}$$

Rearranging:

$$M_s = (M_w \times L_1 + M_n \times L_2 - M_c \times L_3)L_4 \qquad \text{(Equation 4)}$$

By substituting the values in Table 10 into equation 4, the required mass of steel was determined to be 61.25kg. Since the steel plates we planned to use weighed 60kg, we needed two plates, to ensure we had more mass than required. The safety factor was subsequently determined:

$$Sf = \frac{(M_c \times L_3 \ + 2 \times 60 \times L_4)}{(M_w \times L_1 + M_n \times L_2)} \qquad \text{(Equation 5)}$$

Using equation 5, the safety factor was determined to be 1.66.

Once the required quantities were decided, a request was made to the EDMC to manufacture the base plate and additional weights. With the structure incorporating large stock material with little alteration, arrangements were made for the components to be returned after the project so the material could be reused in future orders. In return, the material cost would not be deducted from our budget. The final manufactured product is shown below in Fig. 47.

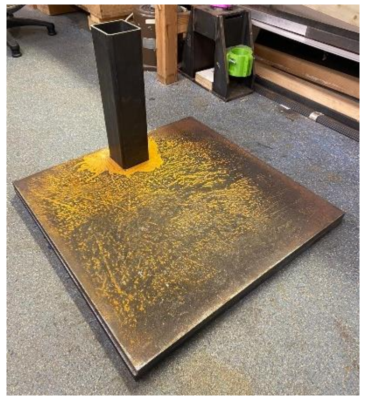


Fig. 47. Image of steel base plate.

5.2.3.2. Frame

The frame of the kissing gate was ergonomically sized, to ensure both pedestrians and mobility scooters have sufficient clearance to pass through comfortably. The clearance for mobility scooters is dependent on the positioning of the slam posts relative to the hang post. Whereas pedestrian clearance relates to the position of the third post joining the two slam posts (here referred to as 'frame post'). Fig. 48 visualises the two 'open' positions of the gate leaf, which correspond to the maximum available clearance to the user. Our design provides a 1030mm clearance for mobility scooters, with static profile data suggesting scooter widths reach up to 685.8mm. The British Standard strongly suggests being able to accommodate a cylinder of 1m diameter inside the frame of the kissing gate [20], allowing for pedestrians using double buggies. Unfortunately, due to the limited space we had, constructing a structure this large would not have been practical. Instead, our kissing gate can accommodate a smaller cylinder of 560mm providing sufficient clearance for pedestrians compared with the average male shoulder width of 465mm (70mm greater than the average female equivalent) [21]. The maximum separation for pedestrians is 685mm between the RADAR strike and frame post, allowing for even greater access with manoeuvring.

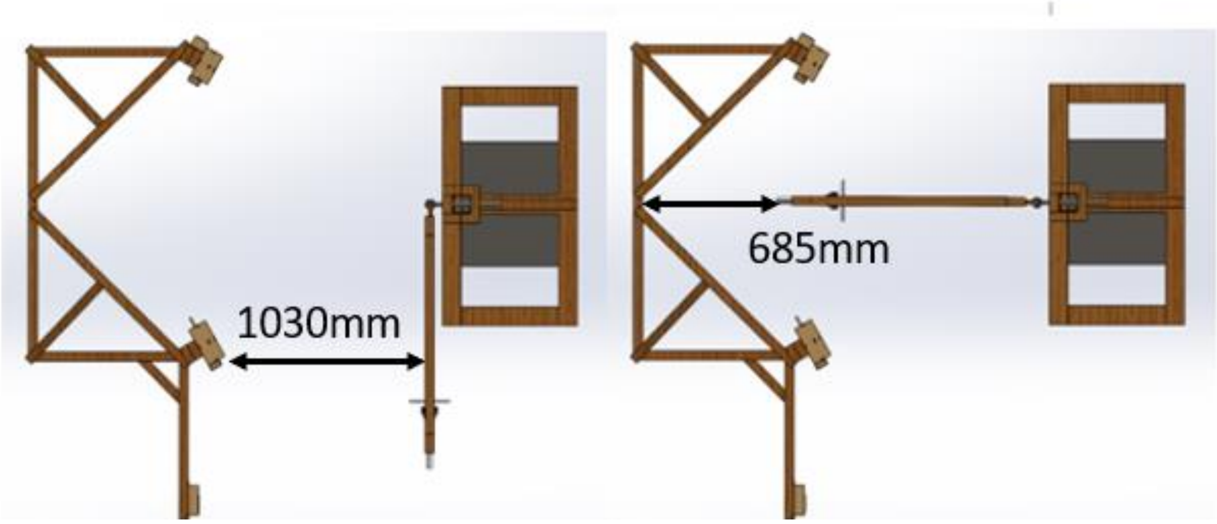


Fig. 48. SolidWorks of clearance distances for mobility scooters (left) and pedestrians (right).

The frame was constructed from the same 45x95mm timber profiles as the gate leaf and hang post, consuming the largest proportion of the material order (8 of the 13 lengths of 3600mm). Much of the structure allowed direct fixing between adjoining pieces, however, the connections between the central frame post and supporting triangular structures proved difficult. Instead, we opted to install angled timber blocks to substitute the connection. We chose this methodology after we found the 90° mounting brackets we purchased were not sufficiently stable. Initial testing of this methodology used L-shaped blocks, as shown in Fig. 49. However, these tended to fail under the force of an impact driver. To remedy this issue, we swapped the L-shape for a triangular profile - providing a stronger connection (Fig. 49).

Fig. 49. Image of broken blocks (left), image of installed blocks (right).

An inherent effect of the frame sizing is the impact on the required length of cables to connect the two pawl housings; a larger structure requires longer cables, increasing component cost. Appendix F displays the engineering drawings of the gate frame as seen from a plan view. It is shown that the length the wires needed to cover was approximately 2.3m. Being prepared for changes in the design, the length of the purchased cable was greater than this value. This allowed for flexible mounting without tensioning or risk of damage, with complete control over the path we ran the cable. We decided it was optimal to mount the cables to the outside of the frame, avoiding contact with the users and being hidden from immediate view.

The pawl housings were mounted directly to the slam posts using metal brackets. This meant that both the weight of the housing, and the force imparted by the gate leaf, would be experienced throughout the post. For this reason, the thickness of the post was doubled by screwing two identical lengths together, forming a 90x95mm profile.

These slam posts were also utilised for the mounting of the RFID reader housings. These boxes were mounted in two positions. Fig. 24 in Section 5.1.2.1 shows how on side B the RFID reader is mounted to the slam post, whereas on side A, the reader is mounted to a wooden protrusion from the post. This protrusion ensures the reader is comfortably placed for the user, due to this being the side where the gate leaf rests and prevents them reaching the slam post. Sizing this additional structure involved referring to our research of mobility scooter models. From our data, we found the average handlebar height of a mobility scooter was around 975mm, whilst the average length was roughly 1700mm. As shown in Fig. 50, from these values we determined a height of 1000mm and a distance from the slam post of 800mm was ideal, allowing the reader to rest marginally above the handlebar height and aligned forward from the scooter's seat. These sizes improved the user experience but also made sure the design did not require excess resources.

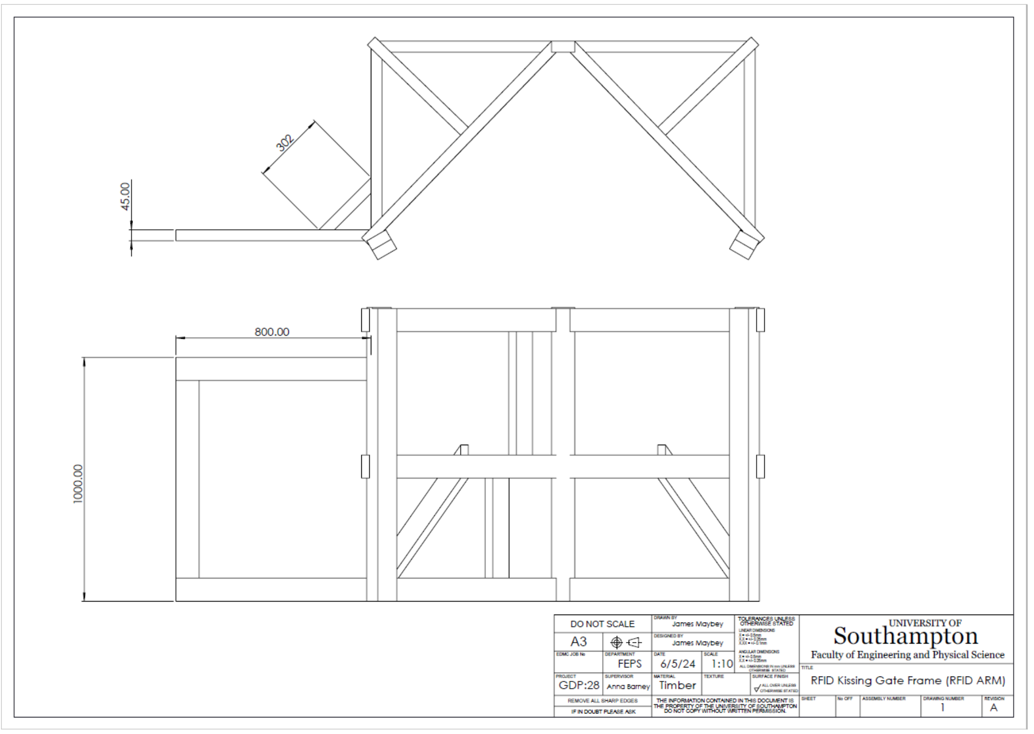


Fig. 50. Drawings of gate frame.

6. Project Management

6.1. Project Plan

The timescale for this project was short, with its duration spanning approximately 8 months. To help manage the resources available, the project was broken down into rough milestones (Fig. 51), which formed the basis of our Gantt chart.

The Gantt chart incorporated critical deadlines and provided us with a guide from project start to completion. A copy of this chart is available in Appendix H. This served as the underlying tool for establishing key dates and organising sub-projects. As expected, significant deviations from the original Gantt chart occurred mostly during the first 3-4 months of the project, due to delays caused by difficulties in developing an adequate design concept. Further delays were imposed by manufacturing lead times, causing testing to be pushed back. To help the group reorganise in response to these delays, the Gantt chart was regularly updated, ensuring that all of the tasks could be completed before the project's due date.

6.2. Resource Management (Budget)

A budget of £850 was initially allocated for the project, with Appendix I showing the breakdown. The total spend was £650.96, with the procurement of materials and manufacturing being the largest category of expenditure (£504.83).

7. Testing

Ideally, the assessment of the success of the prototype would have involved testing its functionality both within the group to evaluate its practical aspects, and with users of mobility scooters, to get relevant user-centric feedback. Additionally, testing with individuals with varying mobility limitations was desirable to evaluate the inclusivity and accessibility of our design across a diverse range of user demographics. The points of assessment are established below.

Design-related criteria evaluated during testing included:

1) Time taken for the gate to close from a full opening.
2) Resting position of self-closing hinges.
3) Maximum dimension that the gate occupies in its complete assembly.
4) Gate robustness.

Inclusivity criteria tested with all users included:

1) Location of RFID readers
2) Is the gate's operation intuitive?
3) Is pedestrian access easy to use?
4) Is the gate leaf easy to push open?

7.1. Methodology

To gather user-centric feedback, we organised a testing session for the prototype structure, so we could assess each aspect of its functionality. An ethics application was prepared and submitted for testing with wheeled mobility aid users, associated with ERGO number: 92418. The risk assessment took into consideration any current or potential hazards that could cause harm to the participants, the public and the assessors. It was essential to evaluate risks and ensure that preventions were implemented prior to testing.

Despite outreach efforts to communities such as the Disabled Ramblers Facebook group, Hampshire RoamAbility Facebook group, and the Neurodiversity and Disability Society; no response was received from any group. Therefore, we were only able to test the design ourselves; using a loaned mobility scooter to obtain user-centred insight.

7.2. Prototype Testing Session

The testing session day was carried out in an indoor location, with various features of the gate assessed as indicated in Table 11. Feedback from an able-bodied person driving a class 2 Invacare Leo mobility scooter was used to assess the RFID and RADAR padlock features.

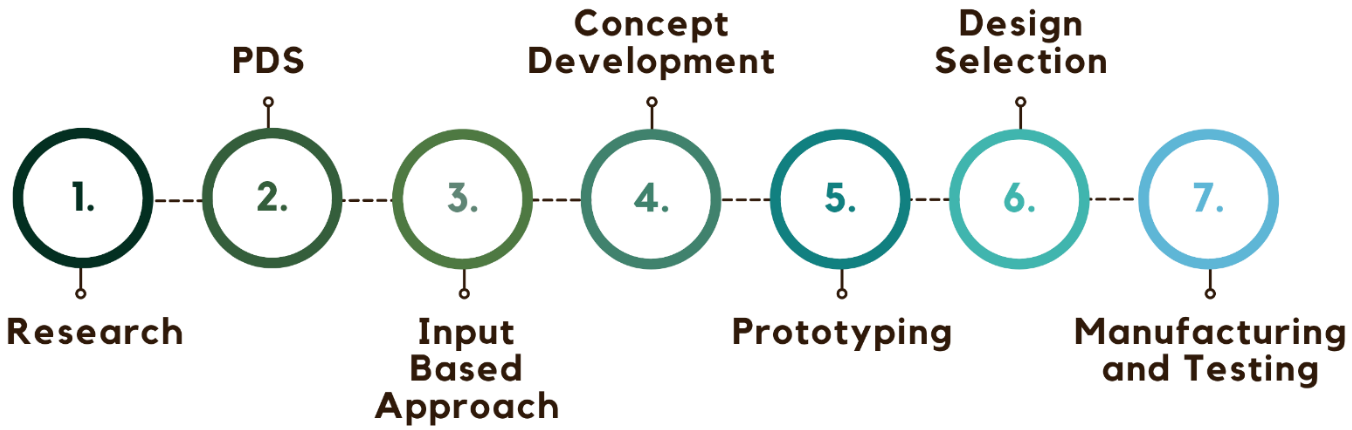


Fig. 51. Overview diagram of design process.

Table 11
Activities and methods used to test gate features.

Test Trials

Activity	**Method**
Assembly of the Gate 	• First full assembly of the gate. • There were issues with alignment of the Pawl Housings with the strike.
Levered-Pawl for Pedestrian Use 	• User walked through one side of the gate, unlatched the strike using the lever. • Once passing through the gate, it was manually latched it closed by pushing the leaf back into the Pawl Housing. • Repeated for both sides of the gate.
RFID Fob 	• User in mobility scooter drove alongside the RFID reader box and tapped the reader with a fob. • Upon activation of the signal light, the user drove through, pushing the gate leaf and allowing the gate leaf to swing back and self-latch. • Repeated for both sides of the gate. • Initial positioning of RFID boxes was suitable so no adjustment was required.
RADAR Padlock 	• User in a mobility scooter drove up to the RADAR padlock, unlocked it using a RADAR key, manually retracted the shoot-bolt and passed through. • Once through, they reversed back to the lock, reset the shoot-bolt and locked it.
Tamper-Proofing 	• Tamper-proofness of the pawl housings and latching mechanism was assessed by attempting to access the pawls through the strike channel and manually lifting them to release the strike. • Both Pawl Housings were able to be cheated.
Self-Close Functionality 	• The self-closing functionality was tested during the RFID fob trials. • The time the pawls were open for was originally set at 30 seconds. • A 10 second interval resulted in an ideal time of the pawls lowering and the strike relatching curing its closing swing.

We successfully assembled and tested the structure, demonstrating its functionality as a proof-of-concept. This process also provided valuable insights into issues and areas for refinement to the design. However, it is also important to acknowledge the inherent limitations to the session. One significant limitation, as previously mentioned, was a lack of feedback from disabled persons that use wheeled mobility aids, with varying vehicle types and disabilities.

7.3. Key Findings + Design Alterations

As discussed, the testing session still proved successful in portraying this proof-of-concept and informing changes. Numerous insights were gained through testing, some requiring small alterations to the design, whilst others demanded complete re-designs of certain components. A list of issues and their recommended solutions are displayed in Table 12.

Table 12
Encountered issues and their suggested solutions.

Encountered Issue	Solution
Alignment of pawl housing strike channels with the strike proved difficult due to tight tolerances	• Increase size of strike channel opening.
The strike would occasionally catch on the lip of the side panel of the pawl housing	• Reconfigure strike channel opening to align flush with the base plate of the pawl housing.
The strike would occasionally slide underneath the pawls, preventing latching	• Increase length of pawls/align pawl resting position to contact the bottom plate. • Reduce tolerances in RADAR strike, to remove excess movement that allows for sliding underneath.
The pawl housings are not tamper-proof as they can easily be accessed from the strike channel and raised	• Add flanges to the exterior of the strike channel.
Strike did not relatch with a 30 second open time	• Open time was reduced to 10 seconds.
The hinges do not come to a rest at the latching post	• Redesign hinges. • Reconfigure gate alignment like existing models and increase length of gate leaf to provide sufficient travel clearance.

All the improvements relating to the pawl housings were incorporated into an improved design (as shown in Fig. 52) such as increased pawl length and a widened strike channel, such that it was flush with the bottom plate. Additionally, as testing took place indoors, it was acknowledged that further iterations of the design would require considerations in outdoor applications. Therefore, a slanted roof was added to aid with rain run-off. This redesign gave the perfect opportunity to further improve the maintenance accessibility. Fixing the overhanging roof with screws allowed for a hinged hatch to be installed. This was held shut by the presence of the roof overhangs sliding over the exterior surface of the door. Once the roof is removed, the hatch allows for free unimpeded access to both the steel pawls and electronics board. This makes electronics maintenance as easy as: unplugging external wired connections, detaching the connecting rod, replacing the entire electronics board, and finally reattaching the wired connections and connecting rod.

Fig. 52. Image of improved design.

8. Project Review

Through having successfully designed, developed, and tested a functioning proof-of-concept, we were able to achieve our project aim and objectives defined at the beginning of the design process. Some of our project milestones and key achievements are identified below:

- By conducting preliminary research from a variety of avenues, such as online sources, the creation of our own questionnaire to gather user and stakeholder opinions and our visit to COAT to get first-hand experience of current gate designs. We were able to determine a variety of issues with current structures which helped us with shaping our design concepts and development of the PDS.
- Additionally, from conversations at COAT, the Gate Workshops, and via feedback from LAFs, we were able to determine additional viewpoints of stakeholders, which helped to inform a more accurate scope of the issue of motorcycles and potential costing of a final gate design.
- The development of a PDS was achieved through consideration of our initial research and interacting with our identified stakeholders.
- Over the course of the project we proposed multiple design solutions, and through evaluation with the design matrix, we were led to choose a concept to prototype.
- We were able to successfully design, construct and test a full-scale prototype of the selected concept.
- While we were not able to test the structure with wheeled mobility aid users, we were still able to test the structure as a group with a mobility scooter, which informed us of adjustments that could be made to the design.

By completing these objectives, we were able to achieve the project aim: design and build a full-scale prototype structure that is motorcycle-deterring, whilst being more accessible for mobility scooter users.

The prototype is more accessible due to the low-effort, one-handed operation enabled by the introduction of ergonomically positioned RFID fobs. The prototype built is not fully motorcycle-restrictive, as the tamper-resistant pawl housing was not as effective as hoped.

However, there are still areas that can be improved, notably the hinge design. Current self-closing hinges do not allow for two-way opening of kissing gates since their resting position cannot be offset. Widening the gate leaf would help with this, as it would produce a comparatively wider clearance gap when driving through the gate. The spring-loaded pin mechanism proposed in section 4.3.2 may provide a solution for this issue, however, the mechanism is complicated and untested.

8.1. Innovation

We feel that our proposed design, using electronics, has provided an alternative approach to agricultural gates, which has not before been established. While the concept of an electronic gate is not new, our application is novel; the integration of electronics within the frame of a kissing gate is previously unseen. The design offers a low-effort user-input using RFID and can be operated with one-hand - making the design more accessible and inclusive. Additionally, the pawl housings and associated electronics were designed to allow easy access for maintenance. Furthermore, an attempt was made to produce a tamper-resistant design, with the creation of a narrow strike-channel; made to complement a custom semi-circular strike profile.

8.2. Process

The evolution of this project is best broken down into four distinct phases: research, design development, manufacturing, and testing. Each of these phases involved unique, individual processes to ensure progression and results. Therefore, to achieve efficient use of our available time and effort, we assigned roles based on individual skillsets. For example, group members proficient in CAD were tasked with producing detailed models of initial concepts, whereas group members experienced in information gathering were given more research-centric roles. Assigning suitable group roles in the project not only helped to provide a hierarchal structure, creating a chain of responsibility, but also allowed for division of tasks to be completed swiftly.

During the design development and manufacturing stages of our project, the design was broken into sub-assemblies; separating the wider gate structure from the pawl housings (and electronics). With testing booked as

a scheduled event, we managed and coordinated the timescales of our tasks and reallocated our focus when delays arose. This adaptability in our work process ensured we were able to build and test our full-scale prototype.

Testing occurred inside a reserved room in Boldrewood Campus, as space was limited in our allocated GDP work area. Originally, we were aiming for the participation of mobility scooter users, however, we received no responses from the organisations we reached out to. Therefore, demonstrations took place using a loaned mobility scooter; allowing us to get an insight into user experience, whilst also highlighting any functional issues with the design.

8.3. Communication

A variety of communication methods are utilised to convey the outputs and relevant information from the project. This includes an assortment of graphical images, circuit diagrams and tables that show our design concepts and technical details.

Design concepts were shown as either hand-drawn sketches, or on CAD modelling software such as SolidWorks. SolidWorks is a crucial medium that allows for transparent and simplified images of the concept we refer to. Further to this, engineering drawings produced from the models give clear insight into the scale of the structure. This basic graphical representation allows both technical and non-technical readers to understand the mechanisms and relevant terminology that is on display. Another way to support non-technical readers is the addition of a terminology table explaining what is being referred to in the main body of the report.

8.4. Sustainability

With sustainable energy generation being a topical issue in the world, it was important that the energy consumption of the prototype was considered and minimised. Therefore, we prioritised using components with low power requirements. Another important aspect of the electronic components selected was their end-of-life management. With maintenance and compartmentalisation being strong features to our design, extraction of the components can be as simple as taking away the damaged board and installing a replacement. This allows for boards to be repaired or components salvaged. Furthermore, regarding prototyping, the pawl housings were constructed from laser cut plywood - minimising material waste. Plywood is also widely recyclable; thus, the prototypes could be dismantled and disposed of in an environmentally friendly manner. This also applies to the timber frame - the largest material contribution to the product.

8.5. Conclusion

The brief set by the Disabled Ramblers at the start of the project proved to be deceptively difficult to design a mechanical solution for, with a few promising ideas emerging but none proving satisfactory enough to carry through to significant prototyping. However, through proper consultation with stakeholders, the true scope of the project was established; opening new avenues of design approach. This new perspective gave rise to the integration of RFID with a kissing gate, increasing access for mobility scooters whilst deterring motorcyclists from accessing the footpath. Hopefully, with continued effort from the Disabled Ramblers' community, this project can evolve into an industry viable solution.

9. Future Work

Having delved into the design phase and reached the testing stage, the team would like to ensure any further developments build upon the foundations laid out. The current prototype, serving as a proof-of-concept involved certain compromises during design and manufacturing. To elevate this design up to market quality, certain modifications are required such as the implementation of renewable energy sources, and further weatherproofing.

9.1. Power Solutions

9.1.1. Connection to Grid

The final prototype we developed was entirely battery-powered – evidently an unfeasible solution if the gate was to be deployed in harsh, outdoor environments for prolonged periods. Therefore, to enhance reliability and decrease maintenance of the system, we recommend powering the gate via a mains connection – a solution we believe to be viable in 'urban fringe' areas, where issues with motorcycles on PRoWs are prevalent.

Mains power providing electricity in the form of Alternating Current (AC) will require a form of converter to derive Direct Current (DC) power. Following that, the output of the AC/DC converter must match the voltage requirement of the battery-powered device, which sees the introduction of a voltage regulator. The inclusion of a circuit

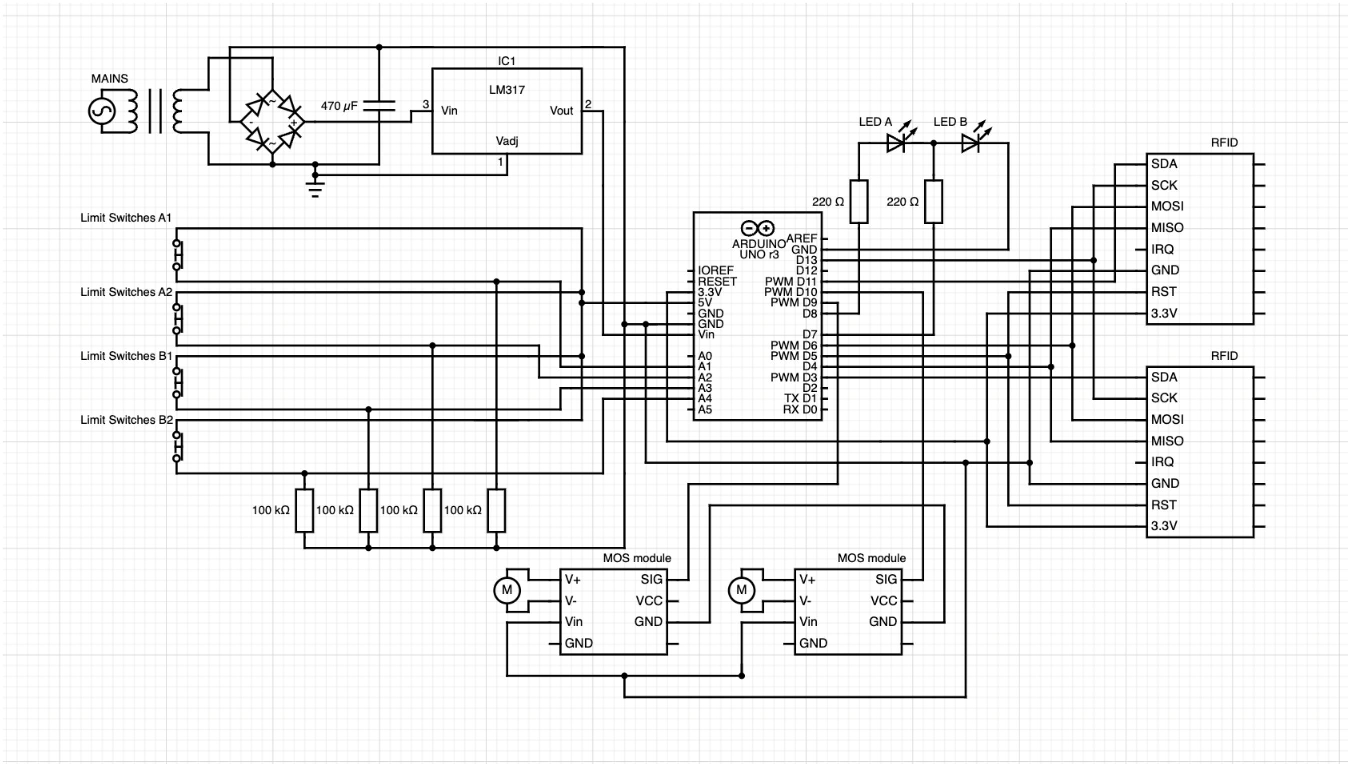


Fig. 53. Circuit diagram with mains power.

protection system and a current-limiting feature to the existing diagram is used to prevent damage and a standard safety practice for electronic circuits. Besides that, isolation of mains supply and low-voltage electronics is critical for safety practices. An illustration of the incorporated components is shown in Fig. 53.

9.1.2. Renewable Energy

In rural areas, where grid infrastructure is limited, renewable energy can be used as an alternative to improve the adaptability, and therefore marketability, of the design. From available renewables, the implementation of solar energy appears to be the most practical solution. The use of solar energy as an alternative source requires the procurement of additional circuit components. The integration of solar panels is needed to capture solar radiation. Moreover, a battery management system, battery, and step-down converter are required to manage the charge levels of the device, as well as powering the existing components. An example circuit diagram with the implementation of a photovoltaic (PV) panel is shown in Fig. 54.

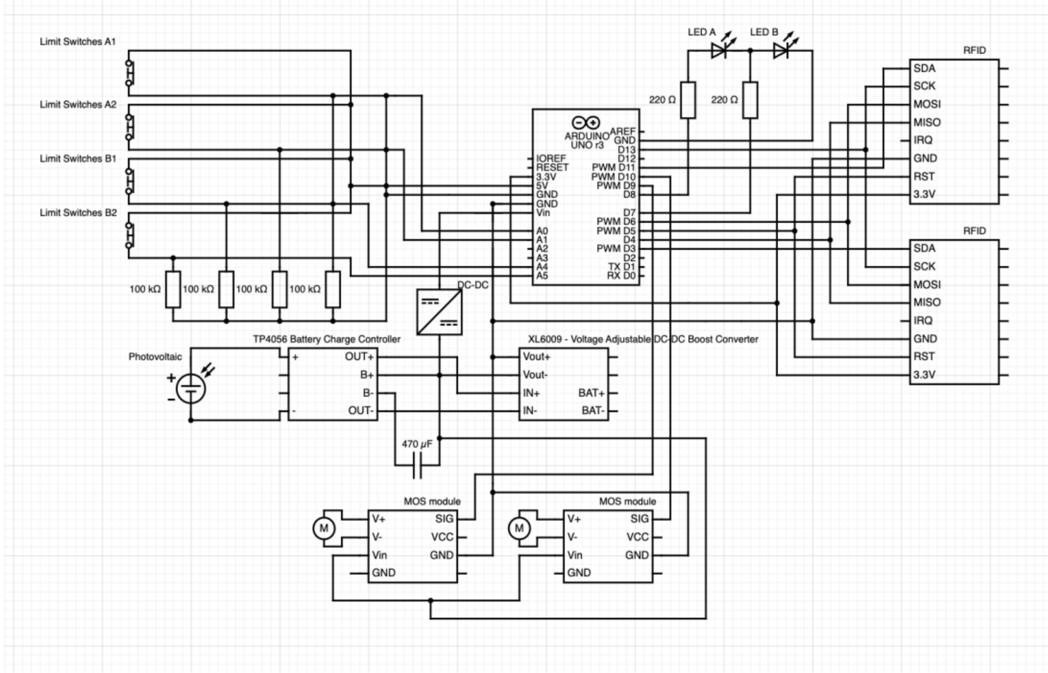


Fig. 54. PV circuit diagram.

During testing, the current draw of all electronic components was determined, such that total power consumption could be calculated (Table 13). For this study an assumption of 80 gate uses per day was made - this figure is arbitrary and can easily be adjusted for specific gate locations. Appendix E shows the methodology in the determination of the daily power draw.

Table 13
Power consumption of individual parts for 80 daily operations.

Component	State	Time (s)	Current (mA)	Avg. Current draw (mA)	Avg. Current draw (A)	Voltage source (V)	Power draw (W)	Total operating time (s)	Total operating time (hr)	Daily Power draw (Wh)
Arduino	Peak	12	88	17.6	0.0176	5	0.088	960	0.011111	0.000978
	Idle	48	77	61.6	0.0616	5	0.308	85440	0.988889	0.304578
Motor A	Peak	2	300	10	0.01	9	0.09	160	0.001852	0.000167
	Idle	58	40	38.66667	0.03867	9	0.348	86240	0.998148	0.347356
Motor B	Peak	2	200	6.666667	0.00667	9	0.06	160	0.001852	0.000111
	Idle	58	40	38.66667	0.03867	9	0.348	86240	0.998148	0.347356
Limit Switch A	Peak	2	15	0.5	0.0005	5	0.0025	160	0.001852	4.63E-06
	Idle	58	3	2.9	0.0029	5	0.0145	86240	0.998148	0.014473
Limit Switch B	Peak	2	15	0.5	0.0005	5	0.0025	160	0.001852	4.63E-06
	Idle	58	3	2.9	0.0029	5	0.0145	86240	0.998148	0.014473
Limit Switch C	Peak	2	15	0.5	0.0005	5	0.0025	160	0.001852	4.63E-06
	Idle	58	3	2.9	0.0029	5	0.0145	86240	0.998148	0.014473
Limit Switch D	Peak	2	15	0.5	0.0005	5	0.0025	160	0.001852	4.63E-06
	Idle	58	3	2.9	0.0029	5	0.0145	86240	0.998148	0.014473
RFID A	Peak	2	26	0.866667	0.00087	3.3	0.00286	160	0.001852	5.3E-06
	Idle	58	13	12.56667	0.01257	3.3	0.04147	86240	0.998148	0.041393
RFID B	Peak	2	26	0.866667	0.00087	3.3	0.00286	160	0.001852	5.3E-06
	Idle	58	13	12.56667	0.01257	3.3	0.04147	86240	0.998148	0.041393
MOSFET A	Peak	2	9.2	0.306667	0.00031	9	0.00276	160	0.001852	5.11E-06
	Idle	58	6.5	6.283333	0.00628	9	0.05655	86240	0.998148	0.056445
MOSFET B	Peak	2	9.2	0.306667	0.00031	9	0.00276	160	0.001852	5.11E-06
	Idle	58	6.5	6.283333	0.00628	9	0.05655	86240	0.998148	0.056445
Total				**220.5633**			**1.46073**			**1.254153**

Considering the power consumption of the circuit (E), a study of the required size for a PV panel was conducted (Table 14, 15, 16). Referring to equation 6; using the average annual irradiation for the Hampshire area (H) [22], and the industry standard average for solar panel yield (r) [23] and performance (PR), the required area of a PV panel (A) could be determined.

Table 14
15 Losses include in the calculations. [24]

Losses Details		
Inverter Losses	8	%
Temperature Losses	8	%
DC cable losses	2	%
AC cable losses	2	%
Shadings	3	%
Losses weak irradiation	3	%
Losses due to weather	2	%
Other Losses	0	%

Table 15
17 Input parameters for PV calculations [25] [22].

Specific photovoltaic power output	PVOUT specific	1060.8	kWh/kWp
Direct normal irradiation	DNI	926.1	kWh/m2
Global horizontal irradiation	GHI	1066	kWh/m2
Diffuse horizontal irradiation	DIF	585.1	kWh/m2
Global tilted irradiation at optimum angle	GTI opta	1252.8	kWh/m2
Optimum tilt of PV modules	OPTA	37/180	º
Air temperature	TEMP	11.2	ºC
Terrain elevation	ELE	34	m

Table 16
16 Calculations for proposed PV output.

E = Energy (kWh)	5.084115
A = Total Solar Panel Area (m2)	0.027
r = solar panel yield (%)	0.2
H = Annual average irradiation on tiilted panels	1256.1
PR = Performance ratio, coefficient for losses	0.75

$$E = A * r * H * PR \quad \text{(Equation 6)}$$

To effectively integrate the PV panel into the design, we suggest that it is fixed atop of the slanted roof of Pawl Housing A (Fig. 55); providing an exposed, flat mounting position. Based on the maximum space available, it is recommended that a PV panel with a surface area of 0.027m^2 is used. Moreover, it is advised that a mounting angle of 37° is utilised to maximise radiation capture [25]. With this optimised PV panel, it is possible to generate ten times the minimum power required for the electronic components. The power generation data for the optimised PV panel is shown in Table 17.

Table 14 17
Calculations for required PV panel size.

Energy	E	0.45777	kWh
Total Solar Panel Area	A	0.00243	m^2
Solar Panel Yield	r	20	%
Annual average irradiation on tilted panels	H	1256.1	kWh/m^2
Performance ratio, coefficient for losses	PR	0.75	

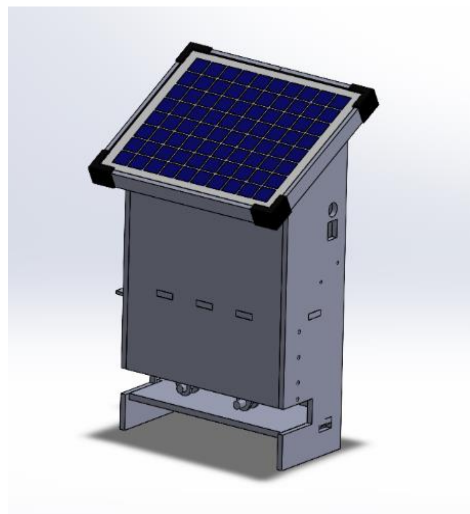


Fig. 55. Possible PV implementation on Pawl Housing.

Due to uncertain weather conditions, it is imperative that the solar module is installed with battery storage, such that the gate receives sufficient power - even in overcast conditions. To ensure the system's reliability, a battery that can store at least a week's worth of energy consumption is recommended.

9.2. Weatherproofing

The working environment of the gate will be hostile, with direct exposure to a variety of extreme weather conditions. Therefore, effective weatherproofing is vital to the sustainability, functionality, and longevity of the gate. Possible suggestions to improve the durability and weather-resistance of the gate are shown in Table 18.

Table 18
Recommendations to weatherproof given gate parts.

Design Aspect	Recommendation
Gate structure	• Substitute material selection to galvanised steel. • Apply protective coatings.
Pawl Housing	• Substitute material selection to galvanised steel. • Tight tolerances in manufacturing. • Incorporate slanted roof to the design. • Reduce the need of joins and connectors. • Incorporate gaskets and sealant when possible. • Incorporate one piece manufacturing where possible.
Electronic components	• Selection of components with a minimum rating of IPX4. • Application of weatherproof coatings. • Proper encasement of wiring incorporated to the structure. • Prevent electrical components from direct outdoor exposure.
Weatherproofing standard	• Should be built to at least an IPX4 standard, but recommendation of IP67 should be done where possible [26].

9.3. Concluding Remarks

The recommendations outlined in this section represent the collective perspectives of the team and offer the opportunity for further development in this project. Should there be any advancements in the future, the team hopes that these suggestions will support and enhance the development process, allowing for more comprehensive and effective outcomes.

10. References

[1]
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11. Appendices

11.1. Appendix A: Static Profile Database

0 = Missing Data	Total weight (kg)	Height without seat (mm) (excluding handlebars)	Width (mm)	Seat width (mm)	Thickness of the actual handlebars (mm)	Height with seat (mm)	Midpoint (mm)	Wheel block height	Ground clearance (mm)	Top handlebar height (mm)	Bottom handlebar height (mm)	Length (mm)	Front tyre size (mm)	Rear tyre size (mm)	If > 2587, we should consider profile
One Rehab Omega 8 (2021)	166		660.4	469.9	0	1358.9	0	0	114.3	0	0	1447.8	330.2	330.2	2189.44825
Galaxy Roadmaster Plus 4 (2020)	140	762	711.2	520.7	30-50	1320.8	1028.8	499.76	139.7	1058.1	999.5	1460.5	355.6	355.6	2241.13725
kymco Maxer (2019)	135	673.1	622.3	482.6	30-50	1168.4	880.15	436.2	165.1	919.1	841.2	1485.9	330.2	330.2	2021.3955
TGA Vita S (2021)	145	952.5	685.8	520.7	30-50	1295.4	855.6	415.8	88.9	895.6	815.6	1397	355.6	355.6	2215.73725
Tramper 4 wheel	146		711.2	605	30-50	1327.8	885.2	535.8	165.1	908.5	861.9	1024.89	3.00-8	3.0 -14	2397.1375
TGA breeze \s4 with hard top canopy and sides	155		685.8	508	0	1689.1	0	0	152.4	0	0	1625.6	304.8	419.1	2586.99
ignite grande	210		770	n/a	0	1480	0	0	95	0	0	1700	355	406	0
Freerider FR1	161	635	685.8	508	30-50	1270	956.85	469.7	152.4	991.6	922.1	1397	330.2	330.2	2167.89
Tramper 3 wheel	140		711.2	n/a	30-50	1099.82	912.8	421.3	129.54	959.6	866	1574.8	3.50x10, 4.00x10, 120/90x10	3.50x10, 4.00x10, 120/90x10	0
Breeze Midi 3	110	1160	630	470	0	1350	0	0	100	0	0	1580/1300	320	320	2180.725
breeze S3	142	1250	770	500	30-50	1420	1172.05	563.5	140	1217.1	1127	1790/1560	420	440	2303.75
TGA Supersport (2020)	125	1016	736.6	508	30-50	1041.4	803.1	441.3	127	847.2	759	1625.6	393.7	495.3	1939.29
Ottobock Wingus (2023)	57		609.6	457.2	0	1041.4	0	0	63.5	0	0	1041.4	330.2	330.2	1849.501
Quickie Q100 R with Standard Seating (2022)	98		584.2	406.4	0	990.6	0	0	50.8	0	0	1041.4	304.8	304.8	1708.912
Quickie Q200 R with Standard Seating With Manual Recline (2022)	37.5		584.2	457.2	0	1244.6	0	0	38.1	0	0	1092.2	330.2	330.2	2052.701
Quickie Q50 R (2022)	37.5		609.6	444.5	0	1003.3	0	0	38.1	0	0	1066.8	304.8	304.8	1788.95375
Rascal Rueba CT (2021)	120.4		647.7	457.2	0	965.2	0	0	50.8	0	0	1092.2	342.9	342.9	1773.301
Pride J600ES (2020)	125		660.4	520.7	0	1168.4	0	0	76.2	0	0	1079.5	342.9	342.9	2088.73725
Invacare Aviva RX20 With Manual Recline (2020)	150		622.3	419.1	0	1041.4	0	0	38.1	0	0	1079.5	342.9	342.9	1782.15925
Pride J600ES (2023)	125		635	482.6	0	1143	0	0	63.5	0	0	1079.5	330.2	330.2	1995.9955
Quantum Edge 3 Stretto with Powered Lift & Tilt (2022)	170		635	469.9	0	1320.8	0	0	76.2	0	0	1244.6	330.2	330.2	2151.34825
Quickie Q300 M Mini (2023)	103		609.6	482.6	0	1333.5	0	0	50.8	0	0	1143	342.9	342.9	2186.4955
TGA Whill Model C (2020)	52		609.6	457.2	0	838.2	0	0	50.8	0	0	990.6	266.7	266.7	1646.301
Invacare Aviva RX40 Modulite Seat Tilt (2021)	150		685.8	482.6	0	1320.8	0	0	38.1	0	0	1130.3	342.9	342.9	2173.7955

Table 19 Mobility scooter database

	Model Type	Measurement				
		Front wheel width [mm]	Back wheel width [mm]	Seat height [mm]	Dimensions L x W x H [mm]	Weight [kg]
1	Amped A60 19/19 40AH 6kw 85cm Red Electric MX Dirt Bike	70	80	850	1900 x 750 x 1100	65
2	10Ten MX-E 3 19/16 50AH 12kw 87cm Electric MX Dirt Bike	70	90	870	1940 x 760 x 1170	105
3	10Ten MX-E 3L 21/18 50AH 12kw 96cm Electric MX Dirt Bike	80	99	940	2160 x 830 x 1300	121
4	10Ten 250RX 21/18 250cc 96cm Dirt Bike	80	90	960	2060 x 800 x 1240	108
5	10Ten 125R 125cc 17/14 86cm Dirt Bike	70	80	860	1680 x 770 x 1100	65
6	10Ten 140R 140cc 17/14 86cm Dirt Bike	70	80	860	1680 x 770 x 1100	85
7	10Ten 250R 19/16 250cc 88cm Dirt Bike	80	90	880	1940 x 790 x 1160	103
19	HONDA CRF450R	80	96	965	2382 x 827 x 1267	110.6
20	HONDA CRF450RX	81	108	965	2182 x 839 x 1282	113.4
21	HONDA CRF250	80	90	961	2177 x 827 x 1265	104
22	HONDA CRF250RX	80	110	964	2176 x 839 x 1281	108
23	HONDA CRF150R	70	90	866	1900 x 770 x 1171	84.4
24	HONDA CRF125F	70	90	785	1770 x 740 x 1010	88
25	HONDA CRF110F	70	80	667	1560 x 686 x 912	74
26	HONDA CRF50F			548	1302 x 581 x 774	50
27	KAWASAKI KX65	60	80	760	1590 x 760 x 955	60
28	KAWASAKI KX85	70	90	830	1829 x 765 x 1100	75
29	KAWASAKI KX112	70	90	871	1920 x 765 x 1150	77
30	KAWASAKI KX250	80	100	860	2190 X 820 X 1270	104
31	KAWASAKI KX450	80	96	960	2180 X 820 X 1270	112.6
32	KAWASAKI KX450R	80	96	955	2185 X 820 X 1265	105.6
33	KAWASAKI KX250X	80	110	945	2170 x 820 x 1260	109.2
34	KAWASAKI KX450X	80	96	950	2175 x 815 x 1260	106.9
35	YAMAHA YZ450F	80	96	965	2180 X 825 X 1275	102
36	YAMAHA YZ250F	80	100	970	2180 X 825 X 1275	98
37	YAMAHA YZ250	80	100	975	2185 x 825 x 1290	95
38	YAMAHA YZ125	80	90	980	2135 x 825 x 1295	94
39	YAMAHA WR450F	84	110	955	2170 x 825 x 1265	117
40	YAMAHA WR250F	80	110	955	2175 x 825 x 1270	115
41	YAMAHA YZ85	70	90	885	1895 x 760 x 1175	73
42	YAMAHA YZ65	60	80	755	1615 x 760 x 1000	62
43	SUZUKI RM-Z450	80	100	960	2175 x 835 x 1260	112
44	SUZUKI RM-Z250	80	90	955	2185 x 835 x 1255	106

Max dimensions
L x W x H
2382 x 839 x 1300

Min. dimensions
L x W x H
1590 x 760 x 755

Models are not taken into account from its significant small profile

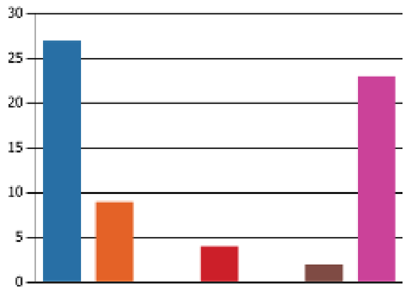
Table 20 Motorcycle database

11.2. Appendix B: Questionnaire

11. What make of wheeled mobility aid(s) do you use when you ramble?

More Details

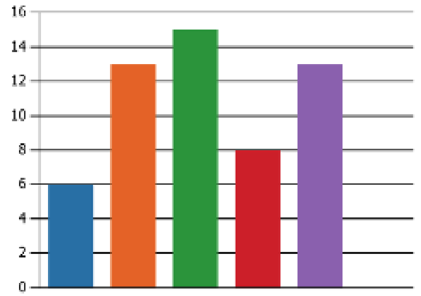
- Tramper 27
- TGA 9
- Galaxy 0
- Breeze 4
- Ottobock 0
- Quickie 2
- Other 23



12. How often do you ramble?

More Details

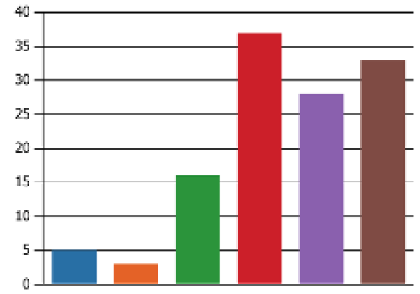
- Daily 6
- 2-4 times a week 13
- Once a week 15
- Once a month 8
- Seasonally 13
- Never 0



13. Do you have any of the following?

More Details

- Restricted hearing 5
- Restricted vision 3
- Restrictions in upper limb move... 16
- Restrictions in lower limb move... 37
- Limited upper limb strength 28
- Limited lower limb strength 33



14. When you do go rambling, what are the conditions are the majority of gates in?

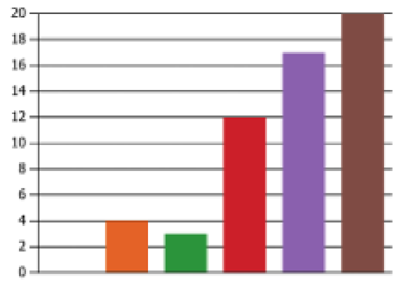
More Details Insights

- **Critical** (gate does not function ... 3
- **Poor** (requires significant force t... 19
- **Fair** (resistance or squeaking wh... 29
- **Good** (slight resistance when op... 5
- **Excellent** (opens/closes smooth... 0

15. How often do you see motorcycles on footpaths or evidence of motorcycles while rambling?

More Details Insights

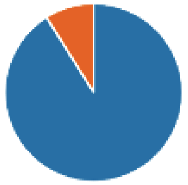
- Always 0
- Very often 4
- Often 3
- Sometimes 12
- Rarely 17
- Never 20



16. Has the thought of needing to use a gate deterred you from any trip?

More Details Insights

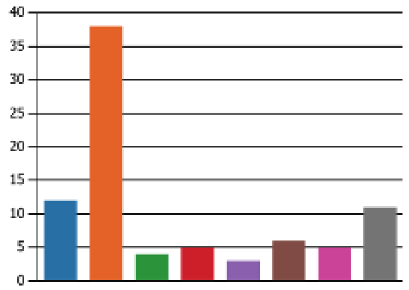
- Yes 51
- No 5



17. Which of the following motions is easiest to perform on a mobility scooter? (you may choose multiple)

More Details

- Pulling towards you 12
- Pushing away from you 38
- Pulling from the ground upwards 4
- Pulling across from right to left 5
- Pulling across from left to right 3
- Pushing across from right to left 6
- Pushing across from left to right 5
- Rotating your wrist (like turning ... 11

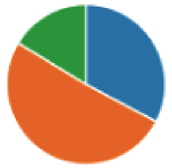


18. Please rate your experience with RADAR locks on outdoor gates.

image: https://www.secure-a-field.co.uk/products/thornton-kissing-gate-with-radar-lock

More Details Insights

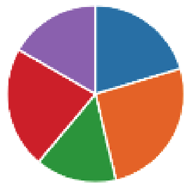
- Negative 18
- Neutral 28
- Positive 9



19. **If you rated your experience** with **RADAR locks** on outdoor gates as **negative**, is this due to:

More Details

- Poor lock quality (seizing up in c... 11
- Inconvenient and difficult to rea... 14
- Too fiddly to use 8
- Having to use a lock at all 12
- Other 9

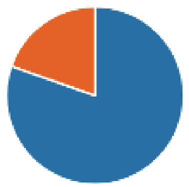


20. Please rate your experience using bike inhibitors.

image: https://centrewire.com/products/motorbike-inhibitor/

More Details Insights

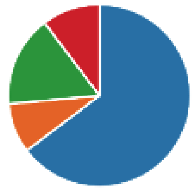
- Negative 45
- Neutral 11
- Positive 0



21. **If you rated** your **experience** with **bike inhibitors** as **negative**, is this due to:

More Details

- Mobility scooter can't fit through 44
- They are physically uncomforta... 6
- It is difficult to align the scooter ... 11
- Other 7

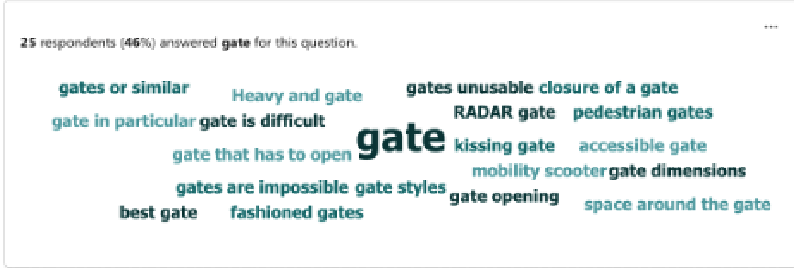


22. What is the most unsatisfactory feature of gates currently in use?

More Details Insights

54 Responses

Latest Responses
"kissing gates "
"See above"
"The existence of old fashioned gates that are impossible for mobility scoot...



23. Are there any pre-existing features of gates that you feel should be universally applied?

More Details Insights

39 Responses

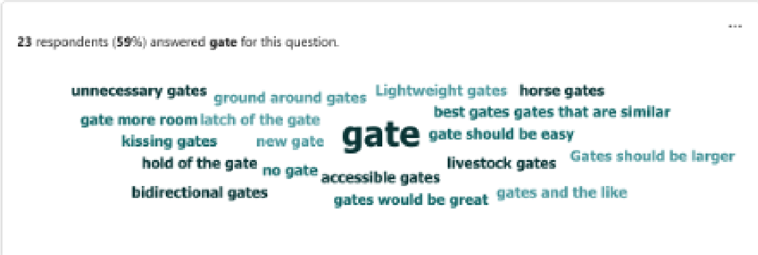
Latest Responses
"More space to manouvre on fenced kissing gates"
"No gate at all unless necessary for eg containment/separation of livestock...
"Thought that would be what your research is all about."

24. Do you have any ideas for new features of gates that you feel would make them more accessible?

More Details Insights

39 Responses

Latest Responses
"on livestock gates that are similar to fenced kissing gate more room to ma...
"Contact "Disabled Ramblers" who have done and are doing lots of work o...



11.3. Appendix C: PDS

	Table 21 PDS document Parameters	
	Competition Best: (Woodstock Large Mobility Kissing Gate)	**Current Model: (Radar Key Kissing Gate)**
Performance Performance demanded should be well defined.	Table 22 PDS document	• Gate open for 12 seconds before closing.
Environment Consider aspects of the products likely working environment.	• Made from galvanised steel so highly resistant to temperature, dirt, corrosion, wind and structural loading environmental effects. • Sunk H-frame posts make it resistant to earth movement rendering it inoperable. • Only RADAR lock is susceptible to freeze jamming, or being corroded/clogged up due to the environment.	• Limit Switches, ethernet cable IP67 rated (waterproof & dustproof) • Electronics housed in sealed compartment at the top of the latch housing. • Linear bearings and carriages can function between -40 °C and 90 °C. • Motor driver can operate between -55°C and 175°C • Max dynamic load of linear carriage 500 N (in direction of load from strike)
Life in Service Should the service life be long or short? Against which part of the PDS should the service life be assessed	Life Span: Exceeding 25 years for hot dipped galvanised steel gates. (https://www.secure-a-field.co.uk/news/2023/03/choosing-rights-of-way-gates)	
Maintenance Is regular maintenance available or desirable?	• In general these galvanised steel gates require maintenance once every 2 years	Enclosure fences can use H-frames to secure positioning, the swinging gate should be fixed to a metal mesh sunk into the floor to keep the gate as level as possible
Target Product Cost Target cost should be established from the outset and compared to competitors products.	£551.00 Maintenance cost low due to use of H-frame. Galvanised steel is tough and weatherproof.	£700.00 Maintenance cost higher due to use of electronic components.
Manufacturing Facility Is the manufacturing facility flexible or does it require specific machinery etc.?	Hooped sections likely to require more complex machinery.	Requires basic manufacturing facilities. Main gate structure can be constructed with straight metal sections.
Weight What weight is desirable. Important consideration when delivery/moving the product.	Woodstock Large mobility: • Gate leaf 19kg • Hooped area 21kg	
Materials Consider if some materials are illegal/should be avoided.	Timbers are unsuitable as the treatments are toxic to the environment and susceptible to warping, however they are commonly found in rural environments for their aesthetic and cost appeal. Hot-dipped galvanised steel is the current standard due to: Corrosion resistance, Strength, Durability, Low maintenance and longevity, Aesthetic versatility through finish options, Sustainability	The prototype does use treated timber but the manufacturable version would use galvanised steel
Standards Which standards may apply to the design? Standards must not be allowed to freeze innovation.	BS5709:2018 compliant **BS5709:2018:** Shape: Sufficient diameter to allow a cylinder w/ diameter of 1000mm to pass through Safety: sharp edges and protruding bolts	Not BS5709:2018 compliant Diameter is insufficient (730 mm), although can be easily adapted
Ergonomics/Use Product should be a 'delight to use'.	**BS5709:2018:** Kissing Gates e.g., (Woodstock Large Mobility) • Gates should swing freely and an opening force no greater than 18N should be reqd. to open fully. • The gate overlap on the closing post shall be greater than 30mm (can be whole gate or just locking tongue.)	Looks to make passing through the gate in two directions, simpler and more efficient, mechanisms at heights informed with scooter and anthropometric data, contactless RFID fobs, possible sinking of a metal mesh to make area flat/level.
Customer Customer input is essential. Input will depend on whether precedents exist already or whether this product stands on its own.	Questionnaire feedback: • Pushing away from you is most comfortable action to perform whilst using a mobility scooter. • Experience with RADAR locks largely neutral.	
Quality	All parts have high durability due to galvanised steel except the RADAR lock which tend to be of lower quality metals that can freeze or suffer jamming due to environmental effects.	Limit switch: 5,000,000 cycles to failure.
Safety State any safety-related aspects of design. These can come from British Standard	**BS5709:2018:** • All edges likely to touch the user must be rounded to a radius greater than 2mm.	
Company, Financial and Time Constraints		Total budget approx.: £850., Testing at the end of April.
Market Constraints Laws/regulations that must be conformed to?	**Equality Act 2010:** Section 20 (4) - 'The second requirement is a requirement, where a physical feature puts a disabled person at a substantial disadvantage in relation to a relevant matter in comparison with persons who are not disabled, to take such steps as it is reasonable to have to take to avoid the disadvantage.' Section 20 (5) - 'The third requirement is a requirement, where a disabled person would, but for the provision of an auxiliary aid, be put at a substantial disadvantage in relation to a relevant matter in comparison with persons who are not disabled, to take such steps as it is reasonable to have to take to provide the auxiliary aid.' https://www.legislation.gov.uk/ukpga/2010/15/section/20	
Politics	Product is stockproof to appease landowners who own livestock - In most cases it is the responsibility of the landowners to install and maintain the gate. There is no clear definition of an unlawful obstruction on a right of way, and it varies on a case-by-case basis. Therefore, to cite motorcycles as justification for the installation for a gate on a RoW requires sufficient evidence to support the claim. https://satinonline.org/Documents/16-a-guide-to-controlling-access-on-paths.pdf There have been legal challenges in the past to improve the level of accessibility to public footpaths in rural areas. However, no legal precedent has been set preventing gates from being constructing solely for the purpose of restricting motorcycle access. One judgement provided by SIr Patrick Elias stated: *'motorcycles are not lawfully there [on public footpaths] and their presence raises an issue of law enforcement'* https://www.bailii.org/cgi-bin/format.cgi?doc=/ew/cases/EWCA/Civ/2021/1098.html&query=(CO/ This judgement is not legally binding.	
Legal Product liability -who is responsible when the product breaks? Consider 'reasonable user expectation, and how a user might interact with a product vs how you intend for the product to be interacted with – not the same thing!	It is Landowners' duty to maintain structures in a safe condition. (https://www.gov.uk/guidance/public-rights-of-way-landowner-responsibilities#structures-for-access)	

11.4. Appendix D: MATRIX

Design Matrix

Design	Aesthetic	Rating	Cost Efficiency	Rating	Manufacturing and material efficiency	Rating	Maintenance	Rating	Ease for Mob. Scooters	Rating	Prevention of motorbikes	Rating	Ease to make 2 way?	Rating	Self Closing	Rating	ccess for additional types of foot traff	Rating	Spatial requirements	Rating	Score
	weighting =	1	weighting =	2	weighting =	3	weighting =	4	weighting =	5	weighting =	5	weighting =	4	weighting =	5	weighting =	3	weighting =	2	
Expanding K-Frame	Artificial shape, stands out from its surroundings	1	Use of electronics and motors, large metal components, additional cost if power is renewable and created at the gate.	1	Electronics need to be integrated into the posts and waterproofed making manufacturing more difficult and expensive.	2	Electronic components will need to be replaced regularly. Waterproof seal may require repair.	1	Ride on mechanism mixed with electronics transforms the gate into a simple gap with relatively little difficulty for the rambler. Alignment of the scooter is the only issue.	5	Ride on mechanism sensitive to the weight. Possible to cheat if minimum weight exceeded.	3	Drive-on mechanism needs to be fitted on both sides. Requires digging on both sides of the gate.	3	Electronics can easily be programmed to shut the gate after a set period of time. Adding an ultrasonic sensor, the gate could check that no one is still in between the frame when closing	5	Walkers can easily pass through and bicycles can dismount and pass through, single prams fit, double prams don't, horse riders don't (suitable for a footpath).	4	Fairly compact, lies within the gate line.	4	110
Ride-On Mechanism	Locks and connections on the floor protrude from the gate leaf which would be visible and stand out from its surroundings.	2	The addition of an intricate mechanism, more materials and more complex manufacturing and installation process makes it expensive.	2	More complicated and involved when compared to the Aston due to increases number of internal parts with smaller tolerances.	2	If an internal part breaks it could require dismantling the entire mechanism to repair it, could fill up and jam with debris.	2.5	Simple to operate as it provides hands-free operation due to only needing to drive-on and push though. However there is an additional challenge of lining up the mobility scooter with the activation mechanism on the floor.	4	The activation mechanism has the potential to be cheated as the average weight of a motorbike and a rider can be estimated to be 50-60 kg each. The design requires 55kg per wedge to trigger and so it may be possible for someone to rest their bike on a wedge and stand on a wedge to unlock the gate.	4	A duplicate drive-on mechanism can be installed at the opposite side.	4	Offset hinge allows for self-closing.	5	No access for extra foot traffic w/o stiles.	2	Requires more space than the Aston as the activation mechanism protrudes away from the gate line on both sides.	2.5	114
Hand Crank RADAR Lock	Crank mechanism housed inside large boxes.	3	Retrofittable to existing gates.	3.5	Complex design with many complex material components, waterproofed making manufacturing more difficult and expensive.	2	Entire gearbox mechanism could seize up due to freezing in the winters.	1	Still requires long and significant use of one arm to crank open .	1.5	Prevented use with RADAR lock.	4	Same as making a normal gate two way.	5	Can be self closing but requires latch release.	3	No access for extra foot traffic without stiles.	2	Very little extra space if mounted to post.	5	98.5
Lever RADAR Key Lock	Comes away from the fence line, uses commonly used parts (lever), Can be made to be fairly sleek.	3	Use of RADAR locks and large lever mechanism with connections to the fence line makes costs acrue.	3	Complex pulley mechanism combined with two post gate, large casing for large area pulleys cover.	3	Hinged hatches will allow for maintenance and replacement of parts inside the gate, also the mechanisms can be designed in sections so easy large replacements can be installed, all metal design means for long lasting durability.	3	Design uses a RADAR lock which are notoriously disliked, large problem with them is their positioning, locks are positioned in hard to reach places and this design solves that, allow the lock to be beside the rider.	3	Designed to be usable with a RADAR key and although this is readily available to most disabled people, motorcyclist could find one, making the lock a big deterrent.	4	By fitting the mechanism on both sides and making them both impact a single latch the design can easily be made two way, with correct hinges, the position of the closing latch into the gate needs to be tuned to be successful.	4	Although the gate can be made self closing by making the latch be released by the closing of the gate, the RADAR lock needs to be closed before driving through and this needs to be clearly sign posted with instructions.	3.5	Provides no access for additional foot traffic, would need to be coupled with stiles or a small kissing gate if space permits.	2	All extensions from the gate are kept to the side, leaving the passage to the gate open and clear.	3	111
Walking Stick/Pole Key	Looks like a gate, however the addition of stiles on the side make it large and unsightly.	4	Lock can be retrofitted so cheap. Pole key requires purchase by user, so may be offputting.	4	Lock design can be fairly simple and so will contain few simple material components with the metal being long lasting and durable, however the lock will have to be high quality in order to avoid seizing of the lock. The pole key is simple and can be made relatively cheaply.	2	Key mechanism may seize up during winter, like radar key mechanisms. So may require replacement.	3	Enable users to open gates from a distance, without having to reach over scooter. Pole key will require good dexterity + hand-eye coordination. Will be a bit fiddly. Need to re-lock after going through gate.	2	Bike users may be able to buy pole key online, therefore gain access to rights of way.	4	Lock can be accessed from both sides.	5	User will need to re-lock gate after they pass through (may require turning).	3	Some access for extra foot traffic via the stile, however this is a low accessability solution as can only allow able bodied persons. It excludes bicylces, horses, those with restricted mobility, pushchairs and potentially dogs.	2	Attached to the gate.	4	109
FID Latch Lifting	Bits of plastic (RFID scanner storage), does not blend well to the environment.	4	Very cheap to install, can be retrofittted. However, can be costly to power with renewables.	2	Requires more materials than most pedestrian gates due to RFID extenstions. Electronic components difficult to recycle.	2	Electronic components will need to be replaced regularly. Waterproof seal may require repair.	2	Can be operated easily, scan and drive through the gate. Positioning of RFID readers away from gate line mean that users don't have reach as far to unlock gate.	4	Masterkey likely to be the same for all gates. Easy to write the tag to a new fob.	4	RFID readers can be accessed on both sides.	5	Self closing hinges combined with electronic latch or pawls mechanism	5	No access for extra foot traffic without stiles.	2	Attached to the gate.	3.5	120
3utton + Motor	Looks like a standard gate with a metal post.	3.5	Electronic components and power can make the system costly.	2	Electronics need to be integrated into the posts and waterproofed making manufacturing more difficult and expensive.	3	The use of electronics will bring down the longetivity of the overall system.	3	Button input opens the gate latch to allow access through the gate leaf, with the button positioned for easy reach.	4.5	No security or discriminating input, therefore anyone can access.	0	Principle function of the hinges is the same as other two-way self closing gates, and the button mechanism can be integrated on both sides.	4	Offset hinge allows for self-closing.	4	Full access for all types of foot traffic.	5	Compact and lies within the gate line.	4	110
Induction Loop	Sensor hidden beneath the ground, metal electronics housing for latch mechanism.	5	Use of electronics require additional power generation.	1	Design needs proper placement of components for it to operate efficiently.	1	The use of electronics will bring down the longetivity of the overall system.	3	Can be operated easily, drive towards the "scanning" area to detect the type of vehicle. Induction identification software doesn't yet exist to single out mobility scooter.	4	Can implement with other sensors to detect the presence of motorbikes.	4	Requires two seperate induction loops to allow two-way use.	3	Self closing hinges combined with electronic latch or pawls mechanism.	5	No access for extra foot traffic without stiles.	2	Require additional distance before the gate for detection area.	2	109
Pull-Up Lever Mechanism	Doesn't look like any existing gates, comes away from the fence line, many chunky square metal components.	2	More expensive for materials and manufacture than a normal gate as there are many components involved.	2.5	All metal parts means long lasting and durable, hinged hatches in the hollow gate posts means the parts and cabling can be installed with reasonable ease, mechanism isnt too complicated, may need pulleys/rollers, design needs levers on both sides of gate for two way usability.	2.5	Hinged hatches will allow for maintenance and replacement of parts inside the gate, also the mechanisms can be designed in sections so easy large replacements can be installed, all metal design means for long lasting durability. Need to find general replacements parts as personally made parts would increase cost.	2.5	Although the design uses a RADAR lock and these are notoriously disliked, we believe a large problem with them is also their positioning, the locks are always positioned in hard to reach places and this design works around that. Allowing the lock to be beside the rider in an more ergonomic location.	4	The gate is design to be usable with a RADAR key and although this is readily available to most disabled people, motorcyclist could go out and find one if necessary, with this considered RADAR lock would still be a successful deterent.	4	By fitting the mechanism on both sides and making them both impact a single latch the design can easily be made two way, with correct hinges. The position of the closing latch into the gate needs to be tuned to be successful.	4	Although the gate can be made self closing by making the latch be released by the closing of the gate, the RADAR lock needs to be closed before driving through - this needs to be clearly sign posted with instructions.	4	Provides no access for additional foot traffic, would need to be coupled with stiles or a small kissing gate if space permits	2	All extensions from the gate are kept to the side, leaving the passage to the gate oepn and clear, however as it extends from the fence line this does require extra space	3	113
RADAR Ramping Bolt Mechanism	Due to the relative large spatial requirements and artificial shape, it is unsightly.	3	Kissing gates cost up to £620 for large woodstock kissing gate, our gate has a more complex mechanism raising the price but uses similar materials.	3	The removal of the latch may reduce cost, however the additional ramping bolt mechanism will increase design manufacturing complexity.	3	H-frame keeps alignment of the posts while galvanised springs would be less susceptible to corrosive damage. Debris is unlikely to stop function as there will be insufficent build-up and access.	3.5	While the design requires an external key which limits accessibility to those without it, it is in an improved position compared to the Aston as the driver can ride alongside it to access it in a more ergonomic position.	4	While the kissing gate structure deters bike users, small or persistent bike users may be able to gain access through the pedestrian route. Alternately bike users may be able to buy the key online.	4	Through barrel allows lock to be accessed from both sides, therefore gate is two-way.	4	Functions similar to an offset hinge which allows for self-closing.	3	its bicycles and prams allows foot traf	4	Kissing gate has relatively large spatial requirements due to the gate leaf and hooped area.	2	119
Aston 2-Way (Benchmark)	Wooden frame is favorable since more inkeeping with environment. No protrusions from the fenceline.	4	£356	3.5	Trombone handle requires bending and is connected to a spring bolt. Gate frame can be constructed out of straight sections of wood.	4	Wooden post may be subject to rot, causing the spring bolt to come out of alignment with latch.	3	Trombone handle easier to reach when compared to gates with easy latch mechanisms only. Trombone handle provides users with more leverage due to length. Users still need to reach over handlebars.	1	No motorcycle prevention measures.	1	Opens in both directions.	5	Offset hinge allows for self-closing. No damping.	5	Provides access for all foot traffic.	5	Compact, no protrusions away from the fence line.	4	113

Table 23 Design matrix

11.5. Appendix E: Power Calculations

Static Ride-On Calculations

First decompose force from mobility scooter to downwards force and inwards force:

$$\cos x \times F = DF$$

$$\sin x \times F = IF$$

Then calculate second moment of inertia for the rod:

$$\frac{H^4}{12} = MI$$

Then find the axial loading and axial extension:

$$\frac{IF}{H^2} = AL$$

$$\frac{(IF \times L)}{E \times H^2} = AE$$

Then for the eccentric loading of the wire calculate eccentricity and eccentric deflection:

$$\sqrt{\frac{IF}{E \times MI}} = \mu$$

$$e \times (\sec(\mu \times L) - 1) = ED$$

Finally calculate eccentric loading:

$$\left(\frac{-IF}{H^2}\right) \times \left(1 + \frac{e \times H^3}{MI} \times \sec(\mu \times L)\right) = EL$$

Determination of power consumption.

Assumption:

Electric components used in this setup exhibits different current draw readings based on their functional status. This analysis will be focusing on two states: operational and idle. To simplify the calculation of power consumption, an approach of average power draw is utilised.

The current draw is measured directly while in operation, while for the idle state values from the specification sheet were utilised. To obtain the average power draw, the need of a weighted average current draw is needed where the duration of the components in its respective state needs to be identified.

$$I_{avg,weighted} = \frac{\sum(I_a \times t_a)}{t_{total}}$$

Where a is defined by its operating state.

$$P_{component} = I_{avg,weighted} \cdot V$$

Where V is the voltage

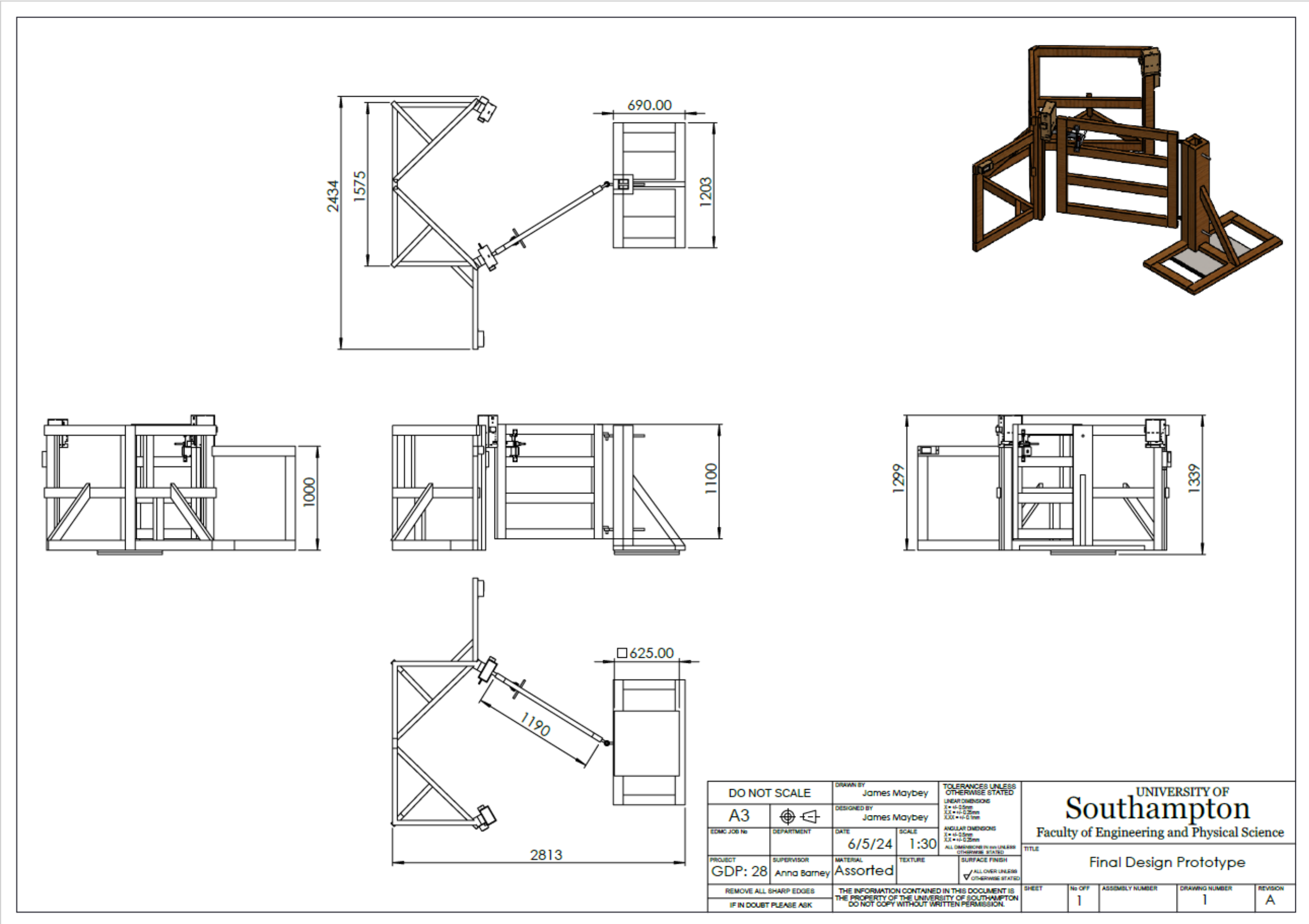
$$P_{tot} = \sum P_{component}$$

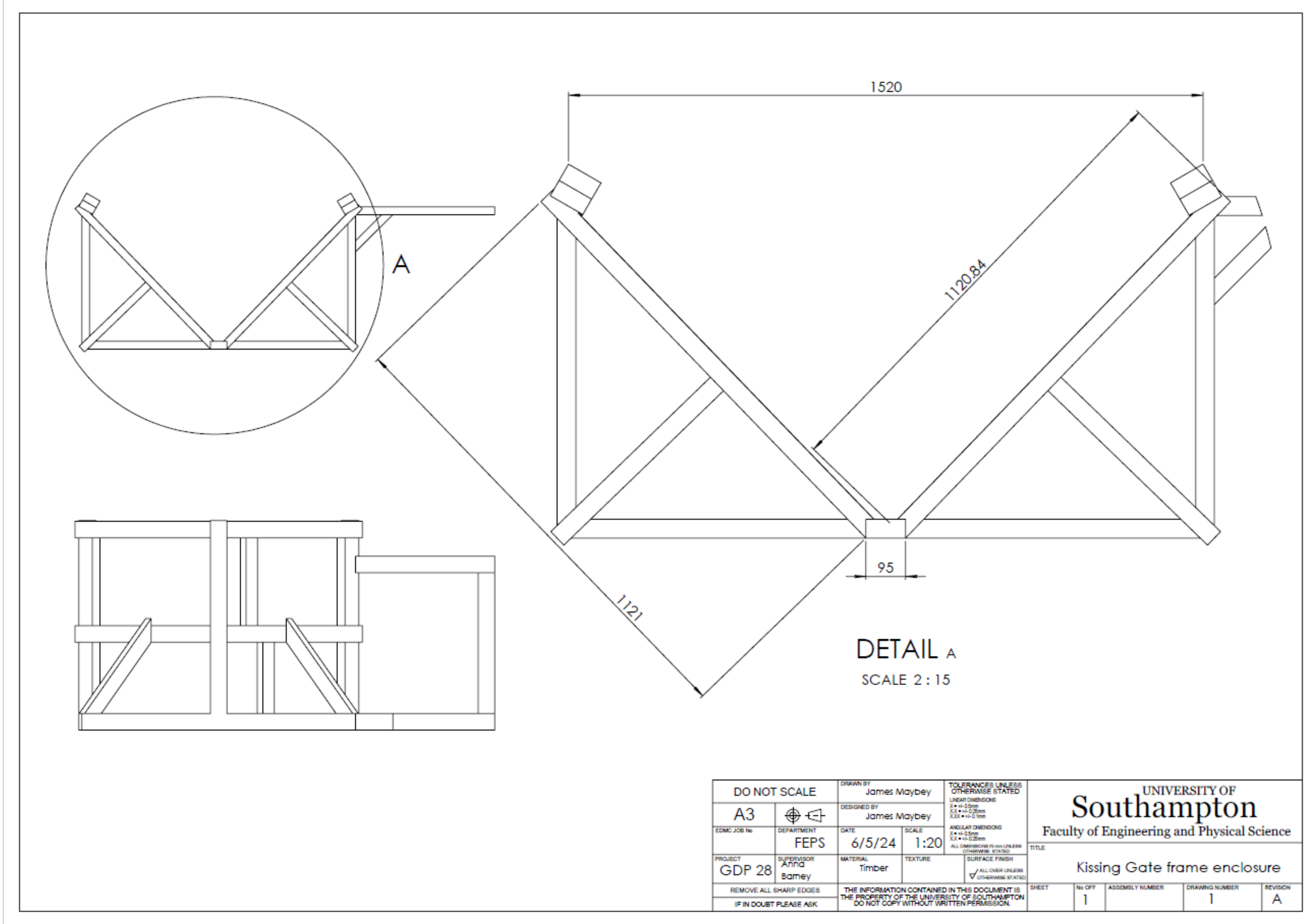
$$P_{draw} = P_{tot} \times t_b$$

Where b is the duration in which the system is operational.

Feasibility study of photovoltaics

11.6. Appendix F: DRAWINGS





11.7. Appendix G: Code Script [27]

```
        RFID_read = 
dump_byte_array(mfrc522[reader].uid.uidByte, 
mfrc522[reader].uid.size);     //add the id of the card to 
the storage string

        if (RFID_read == MasterTag && reader == 
0){state_latch = 4;}  // if the ID is the same as the master 
tag and the reading is taken by reader 1

        else if (RFID_read == MasterTag && reader == 
1){state_latch = 11;}//if the ID is the same as the master 
tag and the reading is taken by reader 0

      }

      }

    if (t_RFID - t_0_RFID > Reading_time){state_latch = 0;}
    break;

    case 4://GO 1 both - start motors and and b
    analogWrite(motorpin_a, motorspeed_a);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 5;
    break;

    case 5://WAIT 1 both- check if motors have both 
completed half rotation

    prev_val_s1a = val_s1a;
    prev_val_s1b = val_s1b;

    delay(10);

    val_s1a = digitalRead(pin_s1a);
    val_s1b = digitalRead(pin_s1b);

    if(val_s1a == LOW && prev_val_s1a == HIGH){
      analogWrite(motorpin_a, 0);
      latch_a_open = true;
    }

    if(val_s1b == LOW && prev_val_s1b == HIGH){
      analogWrite(motorpin_b, 0);
      latch_b_open = true;
    }

    if(latch_a_open == true && latch_b_open == 
true){state_latch = 6;}
    break;

    case 6:// both 1/2 ROTATION COMPLETE
    t_0_open = millis();
    //digitalWrite(LED_A, HIGH);
    state_latch = 7;
    break;

    case 7: //both OPEN TIME - start timing how long both 
latches have been open for
    t_open = millis();
    if(t_open-t_0_open > go_through_time){state_latch = 8;}
    break;

    case 8: //GO both 2 - if gate open for long enough, 
start motor again
    //digitalWrite(LED_A, LOW);
    analogWrite(motorpin_a, motorspeed_a);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 9;
    break;

    case 9:// WAIT both 2 - check if motors have completed 
another half rotation

    prev_val_s2a = val_s2a;
    prev_val_s2b = val_s2b;

    delay(10);

    val_s2a = digitalRead(pin_s2a);
    val_s2b = digitalRead(pin_s2b);

    if(val_s2a == LOW && prev_val_s2a == HIGH){
      analogWrite(motorpin_a, 0);
      latch_a_open = false;
    }


    if(val_s2b == LOW && prev_val_s2b == HIGH){
      analogWrite(motorpin_b, 0);
      latch_b_open = false;
    }

    if(latch_a_open == false && latch_b_open == 
false){state_latch = 10;}
    break;

    case 10: //ROTATION COMLETE
    state_latch = 0;
    break;

    case 11://GO 1a - start motor a
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 12;
    break;

    case 12://WAIT 1a - check if motor a has completed half 
rotation

    prev_val_s1b = val_s1b;

    val_s1b = digitalRead(pin_s1b);

    if(val_s1b == LOW && prev_val_s1b == HIGH){state_latch = 
13;}
    break;

    case 13://Motor_a 1/2 ROTATION COMPLETE
    analogWrite(motorpin_b, 0);
    t_0_open = millis();
    //digitalWrite(LED_B, HIGH);
    state_latch = 14;
    break;

    case 14: //OPEN TIME_a - start timing how long gate has 
been open for
    latch_b_open = true;
    t_open = millis();
    if(t_open-t_0_open > go_through_time){state_latch = 15;}
    break;

    case 15: //GO 2a - if gate open for long enough, start 
motor again
    digitalWrite(LED_B, LOW);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 16;
    break;

    case 16:// WAIT 2a - check if motor has completed 
another half rotation

    prev_val_s2b = val_s2b;

    val_s2b = digitalRead(pin_s2b);

    if(val_s2b == LOW && prev_val_s2b == HIGH){state_latch = 
17;}
    break;

    case 17: //STOP motor a
    analogWrite(motorpin_b, 0);
    latch_b_open = false;
    state_latch = 10;
    break;

  }
}


 String dump_byte_array(byte *buffer, byte bufferSize){// 
this function takes the reading from the RFID reader and 
turns it into a string
```


```
        RFID_read = 
dump_byte_array(mfrc522[reader].uid.uidByte, 
mfrc522[reader].uid.size);     //add the id of the card to 
the storage string

        if (RFID_read == MasterTag && reader == 
0){state_latch = 4;}  // if the ID is the same as the master 
tag and the reading is taken by reader 1

        else if (RFID_read == MasterTag && reader == 
1){state_latch = 11;}//if the ID is the same as the master 
tag and the reading is taken by reader 0

      }

      }

    if (t_RFID - t_0_RFID > Reading_time){state_latch = 0;}
    break;

    case 4://GO 1 both - start motors and and b
    analogWrite(motorpin_a, motorspeed_a);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 5;
    break;

    case 5://WAIT 1 both- check if motors have both 
completed half rotation

    prev_val_s1a = val_s1a;
    prev_val_s1b = val_s1b;

    delay(10);

    val_s1a = digitalRead(pin_s1a);
    val_s1b = digitalRead(pin_s1b);

    if(val_s1a == LOW && prev_val_s1a == HIGH){
      analogWrite(motorpin_a, 0);
      latch_a_open = true;
    }

    if(val_s1b == LOW && prev_val_s1b == HIGH){
      analogWrite(motorpin_b, 0);
      latch_b_open = true;
    }

    if(latch_a_open == true && latch_b_open == 
true){state_latch = 6;}
    break;

    case 6:// both 1/2 ROTATION COMPLETE
    t_0_open = millis();
    //digitalWrite(LED_A, HIGH);
    state_latch = 7;
    break;

    case 7: //both OPEN TIME - start timing how long both 
latches have been open for
    t_open = millis();
    if(t_open-t_0_open > go_through_time){state_latch = 8;}
    break;

    case 8: //GO both 2 - if gate open for long enough, 
start motor again
    //digitalWrite(LED_A, LOW);
    analogWrite(motorpin_a, motorspeed_a);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 9;
    break;

    case 9:// WAIT both 2 - check if motors have completed 
another half rotation

    prev_val_s2a = val_s2a;
    prev_val_s2b = val_s2b;

    delay(10);

    val_s2a = digitalRead(pin_s2a);
    val_s2b = digitalRead(pin_s2b);

    if(val_s2a == LOW && prev_val_s2a == HIGH){
      analogWrite(motorpin_a, 0);
      latch_a_open = false;
    }


    if(val_s2b == LOW && prev_val_s2b == HIGH){
      analogWrite(motorpin_b, 0);
      latch_b_open = false;
    }

    if(latch_a_open == false && latch_b_open == 
false){state_latch = 10;}
    break;

    case 10: //ROTATION COMLETE
    state_latch = 0;
    break;

    case 11://GO 1a - start motor a
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 12;
    break;

    case 12://WAIT 1a - check if motor a has completed half 
rotation

    prev_val_s1b = val_s1b;

    val_s1b = digitalRead(pin_s1b);

    if(val_s1b == LOW && prev_val_s1b == HIGH){state_latch = 
13;}
    break;

    case 13://Motor_a 1/2 ROTATION COMPLETE
    analogWrite(motorpin_b, 0);
    t_0_open = millis();
    //digitalWrite(LED_B, HIGH);
    state_latch = 14;
    break;

    case 14: //OPEN TIME_a - start timing how long gate has 
been open for
    latch_b_open = true;
    t_open = millis();
    if(t_open-t_0_open > go_through_time){state_latch = 15;}
    break;

    case 15: //GO 2a - if gate open for long enough, start 
motor again
    digitalWrite(LED_B, LOW);
    analogWrite(motorpin_b, motorspeed_b);
    state_latch = 16;
    break;

    case 16:// WAIT 2a - check if motor has completed 
another half rotation

    prev_val_s2b = val_s2b;

    val_s2b = digitalRead(pin_s2b);

    if(val_s2b == LOW && prev_val_s2b == HIGH){state_latch = 
17;}
    break;

    case 17: //STOP motor a
    analogWrite(motorpin_b, 0);
    latch_b_open = false;
    state_latch = 10;
    break;

  }
}


 String dump_byte_array(byte *buffer, byte bufferSize){// 
this function takes the reading from the RFID reader and 
turns it into a string
```


```
  String RFID_read = "";

  for (byte i = 0; i < bufferSize; i++) {
    RFID_read.concat(String(buffer[i] < 0x10 ? " 0" : " 
"));
    RFID_read.concat(String(buffer[i], HEX));
   }

  RFID_read.toUpperCase();
  RFID_read = RFID_read.substring(1);

 return RFID_read;
 }
```

11.8. Appendix H: Gantt chart

GDP Gantt Chart

Access Gate for Disabled Ramblers - Project 28

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	Percent Completed
Initial Group Meeting	1	1	1	1	100%
Initial Supervisor Meeting	1	1	1	1	100%
Initial Charity Contact Meeting	2	1	2	1	100%
Role Allocation	2	1	2	1	100%
Background Research	2	11	2	3	100%
Idea Generation	3	11	2	16	100%
Risk Assessment for COAT visit and EDMC	4	2	4	2	100%
Presentation Prep	4	2	4	2	100%
COAT visit	5	1	5	1	100%
Elevator Pitch	6	2	6	0	N/A
EDMC Consultation	6	2	8	1	100%
Prototyping	8	8	15	4	100%
Submit P2 Form	8	2	13	1	100%
Formal Meeting Review	9	2	9	2	100%
Peer Feedback Forms Sem 1	10	1	10	1	100%
Design Finalisation	11	3	18	2	100%
Ethics	12	4	12	18	100%
Manufacturing	22	4	24	8	100%
Testing	22	6	31	2	100%
Report	22	10	27	7	100%
User Testing	29	1	31	1	N/A
Video	29	6	31	3	100%
Peer Feedback	34	1	34	1	100%

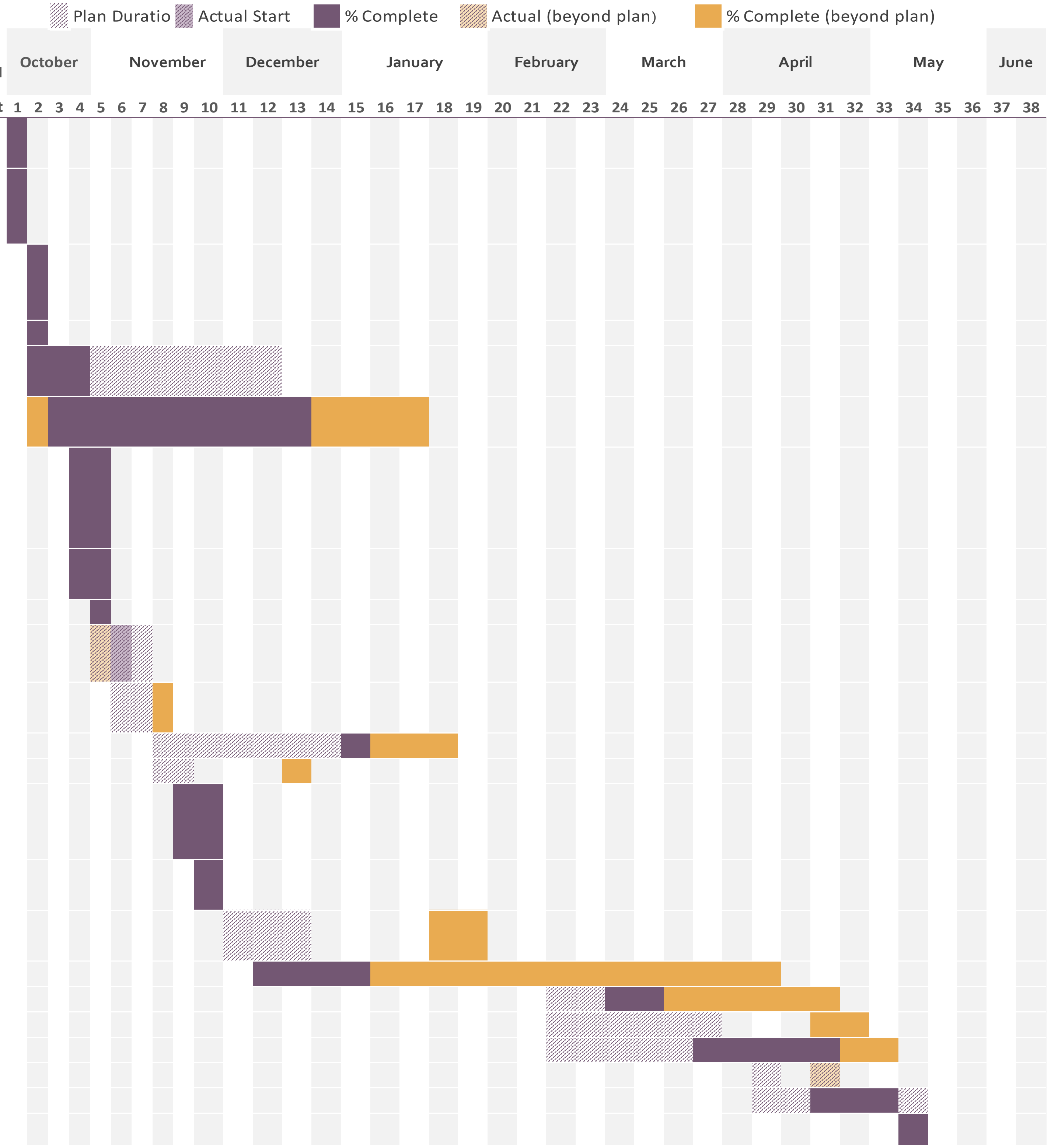


Fig. 56 GDP timeline

11.9. Appendix I: Budget

Expenses				
Item	**Description**	**Quantity**	**Unit Cost**	**Amount (£)**
Electronics	Cat 5 Ethernet Cable	1	£ 3.25	£ 3.25
Electronics	Cat 6 Ethernet Cable	1	£ 6.46	£ 6.46
Electronics	Motor	2	£ 21.09	£ 42.18
Electronics	Motor Driver	2	£ 5.99	£ 11.98
Electronics	RFID Reader	2	£ 3.70	£ 3.70
Electronics	RJ45 Breakout Boards	2	£ 10.99	£ 21.98
Manufacturing	Back up Radar EDMC	1	£ 30.00	£ 30.00
Manufacturing	Latch waterjet cut	1	£ 5.00	£ 5.00
Materials	Angle Brackets	1	£ 23.70	£ 23.70
Materials	Centrewire hinge kits.	1	£ 80.40	£ 80.40
Materials	Hex-flange screws	2	£ 13.29	£ 26.58
Materials	Padlock for Radar Key	1	£ 21.60	£ 21.60
Materials	Radar key	1	£ 6.00	£ 6.00
Materials	Wood (including stiles)	1	£ 222.00	£ 222.00
Miscellaneous	F&B reimbursement	1	£ 10.00	£ 10.00
Transportation	COAT visit	1	£ 136.13	£ 136.13
Subtotal				**£ 650.96**
Budget Left				**£ 199.04**

Electronics	£ 89.55
Manufacturing	£ 35.00
Materials	£ 380.28
Miscellaneous	£ 10.00
Transportation	£ 136.13
Unspent	£ 199.04

Table 24 Budget breakdown

Expenses				
Item	Description	Quantity	Unit Cost (£)	Total Cost (£)
Components	Centrewire 180 degree hinge kits.	1	80.4	80.4
Components	Radar key	1	6	6
Components	Padlock for Radar Key	1	21.6	21.6
Electronics	Arduino	1	25	25
Electronics	Limit Switches	4	1.32	5.28
Electronics	Cables	1	6	6
Electronics	Cat 6 Ethernet Cable	1	6.46	6.46
Electronics	Cat 5 Ethernet Cable	1	3.25	3.25
Electronics	Motor	2	21.09	42.18
Electronics	Motor Driver	2	5.99	11.98
Electronics	RJ45 Breakout Boards	2	10.99	21.98
Electronics	RFID Reader	1	3.7	3.7
Manufacturing	Back up Radar EDMC	1	30	30
Manufacturing	Latch waterjet cut	1	5	5
Material	Hex-flange screws	2	13.29	26.58
Material	Angle Brackets	1	23.7	23.7
Material	Wood (including stiles)	1	112	112
Material	Linear Rails	0.3	57	17.1
Material	Linear Guide Carriage	4	23.27	93.08
Subtotal				541.29

Table 25 Cost breakdown of the prototype